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Propane Dehydrogenation by Autothermal Reforming

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Abstract
The proposed design is for the the production of propene through propane dehydrogenation using Thyssen Krupp's STAR technology and a hybrid membrane separation. The plant has a capacity of 700 kT/yr and will be located in the Middle East. At current propane/propene prices, the use of Thyssen Krupp's STAR process and hybrid membrane separation is not economical and has a negative IRR. The NPV of this project at current market prices is -$865MM. However, economic feasibility depends on volatile market conditions. The process begins with the oxydehydrogenation section, consisting of four reformers connected to four oxyreactors that are cycled to allow for regeneration of the .2-.6%Pt- Sn/$ZnAl_2O_5$ catalyst. In order to produce polymer grade propene, a separation is needed following dehydrogenation. Separation operations include adsorption, MEA absorption system, distillation, and a hybrid distillation/membrane C3 splitter.

Disciplines
Biochemical and Biomolecular Engineering | Chemical Engineering | Engineering

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April 12, 2015

Hello Dr. Gorte and Professor Fabiano,

Enclosed you will find a proposed process design for the industrial production of polymer-grade propene through the oxydehydrogenation of propane as proposed by Mr. Wismer. The presence of oxygen as a feed results in an increased conversion of propane in the second reactor as well as the exothermic conversion of the hydrogen byproduct which allows for autothermal reforming.

The design uses technology licensed from the STAR process by Thyssen Krupp and involves the dehydrogenation of propane over a .2-.6%Pt-Sn/$ZnAl_2O_5$ catalyst in the presence of steam. The effluent is then sent to a second reactor along with pure oxygen. Conventional propane dehydrogenation requires considerable heat to satisfy the endothermic heat of reaction and the conversion per pass is equilibrium limited. The contents are taken to an adsorption column to remove water from the system. After this step, the product stream is sent to an an MEA absorption system to remove carbon dioxide and then another distillation column to remove hydrogen, carbon monoxide and light components. The resulting stream of C3 hydrocarbons is then sent to a novel hybrid system consisting of a distillation column and membrane separation to separate the propane and propene. The proposed plant with be located in the Middle East and has the capacity to produce 700 kT/yr of polymer grade propene.

This report contains detailed process design, economic analysis, and conclusions and recommendations for the implementation of the plant. At current raw material costs, the proposed design is economically feasible at a propene price of $0.43. At current propene prices, the estimated IRR is negative and the NPV is -$865,000,000. The continuous operations in this process were modeled using Aspen Plus v8.6. Cost estimates for the equipment were obtained using the equations contained in Process Design Principles, 3rd Edition, by Seider, Seader, Lewin and Widagdo.

Thank you for the assistance afforded to us during this project.

Sincerely,

Jeff Barsamian

Jayant Rao

Patrick Staiber

Eric Wamakima

Jeff Barsamian | Jayant Rao | Patrick Staiber | Eric Wamakima

Propane Dehydrogenation by Autothermal Reforming

Senior Design Project, CBE 459
Project submitted to: Dr. Raymond Gorte
Prof. Leonard Fabiano
Project proposed by: Mr. John Wismer

Department of Chemical and Biomolecular Engineering
School of Engineering and Applied Science
University of Pennsylvania
April 12, 2016

Table of Contents

Abstract

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The process begins with the oxydehydrogenation section, consisting of four reformers connected to four oxyreactors that are cycled to allow for regeneration of the .2-.6%Pt-Sn/$ZnAl_2O_5$ catalyst. In order to produce polymer grade propene, a separation is needed following dehydrogenation. Separation operations include adsorption, MEA absorption system, distillation, and a hybrid distillation/membrane C3 splitter.

Introduction

As demand increases for propene, the basis of the bulk polymer polypropylene, there has been significant research on alternatives to traditional propene production. Historically, propylene has been supplied a by product of refinery catalytic crackers and olefin plants that use naphtha or gas oil feedstock. However, in recent years, the decline in US gasoline consumption combined with the displacement of naphtha by ethane as a feedstock for olefin crackers has led to a decline in by-product propene production. These trends are expected to continue for the foreseeable future as new ethane-supplied crackers come on stream. As a result, propene will be increasingly supplied by on-purpose production. Although ethylene metathesis may play a bigger role in the future if ethylene prices drop as expected, the current preferred on-purpose route is propane dehydrogenation. This has typically been done in catalytic high temperature reactors.

Propane dehydrogenation requires considerable heat to satisfy the endothermic heat of reaction and the conversion per pass is equilibrium limited. Additionally, the separation of propane and propene is very energy intensive. In 2014, Thyssen Krupp developed the STAR process to combat these issues. This technology uses oxydehydrogenation as an alternative to direct dehydrogenation. In this technology, oxygen is co-fed to the reactor to react exothermically with the hydrogen produced by dehydrogenation (Herauville, 2012). Thus, the heat of combustion can be used to supply heat for the dehydrogenation reaction. Additionally, the consumption of hydrogen allows the equilibrium conversion of propane to propene to increase. The higher propylene content of the reactor allows for a less energy intensive C3 separation.

Current methods of the C3 separation involved in propane dehydrogenation processes are very energy intensive as well. Conventional distillation can require up to 200 theoretical stages

and reflux ratios greater than 10. One promising alternative to distillation is membrane separation. A recent membrane development is to use a composite of resins and molecular sieves. Although not commercially available, ZIF-8, is showing promise in both C3 splitting and CO2 purification. There has been some indication that a hybrid process using both distillation and membranes may be optimal. This project attempts to quantify the feasibility of this system.

There are five licensed technologies for propane dehydrogenation: CATOFIN from Lummus Technology, Oleflex from UOP, Fluidized Bed Dehydrogenation from Snamprogetti, STAR process from Thyssen Krupp Udhe, and PDH from Linde/BASF. The main differences between these technologies are the type of catalyst, regeneration methods, reactor design, and methods used to increase conversion. Although all these technologies have their strengths and weaknesses, the scope of this project was to evaluate one of these technologies. This project evaluates the potential of the STAR process and a hybrid membrane separation to produce propene.

The process begins with the oxydehydrogenation section, consisting of four reformer-oxyreactor complexes that are cycled to allow for catalyst regeneration. Various separations are performed after to get a polymer grade purity (>99.5%). Separation operations include a water adsorption system to recycle water, monoethanolamine CO_1 capture system, distillation column to recover hydrogen and light hydrocarbons and a hybrid membrane C3 splitter. The NPV and IRR of this process is highly sensitive to the price margin between propane and propene. The price margin is currently relatively small for propene and propane at current market conditions, making the process uneconomical. In order to determine the most economical type of on-purpose PDH process, a complete analysis of all five technologies should be conducted.

The proposed plant will be located in Middle East and will produce 700 kilotons of propene a year. This location was chosen to supply the propene needs in the Middle East and Europe (ICIS, 2016). The project will able to avoid the current supply glut of propene in China by focusing on supplying these markets. This location will also minimize propane costs because propane feed stocks are readily available from the oil refinery operations there.

Objective-time Chart

Project Name	Propane Dehydrogenation by Autothermal Reforming
Project Champions	Mr. John Wismer, Dr. Raymond Gorte, Dr. Leonard Fabiano
Project Leaders	Jeff Barsamian, Jayant Rao, Patrick Staiber, Eric Wamakima
Specific Goals	Evaluate the potential of an on-purpose propene plant with a capacity of 500kT/year using propane oxydehydrogenation and hybrid membrane separation
Project Scope	In scope: • Design of oxydehydrogenation reactor complex • Design of gas separation unit • Design of hybrid membrane separation to achieve polymer grade 99.5% wt. purity • Market and profitability analysis • Determination of plant location Out of scope: • Distribution of final propene product
Deliverables	Business Opportunity Assessment • What is the market for propene? • What competitors currently produce propene? Manufacturing Capability Assessment: • Can the plant be built with reasonable capital investment?
Timeline	Complete design and economic analysis by April 12, 2016

Market and Competitive Analysis

Propene Uses

Propene is available in three grades of various purities: refinery grade (60-70%), chemical grade (93-94%), and polymer grade (minimum of 99.5%). The most common use of propene is polypropylene, which accounts for almost two thirds of global propene consumption. Polypropylene is one of the most versatile bulk polymers because of its excellent mechanical and chemical properties and has found uses in a variety of consumer and industrial products. Polypropylene and polypropylene alloys account for a third of the plastics used in the automobile sector. Injection molded polypropylene is used in electrical appliances, household goods, and toys. Film grade polypropylene is used in packaging, and polypropylene can be extruded into pipes, wire and cable. Although polypropylene experienced high levels of growth in the 1990s but has since dropped to around 5% a year due to the increased price of propylene compared to other base chemicals (ICIS, 2010).

Propene is also used in acrylonitrile, which is used to make acrylic fibers. Acrylic fibers have a variety of applications, from clothing to home furnishings. The third largest use of propene is for propylene oxide, and intermediate for the production of flexible foams and propylene glycol ethers. Other uses of propene include various alcohols, cumene, and acrylic acid.

Propene Market Overview

In the long term, reduction in propene supplies from steam crackers and refineries together with the resulting higher price levels are supporting investments in on-purpose production (IHS, 2016). In the short term, however, the market price for propylene is heavily influenced by the current global oversupply due to improved production and softer demand (ICIS

News, 2015). This oversupply is expected to persist and continue to affect the price of propene and its derivatives. US propene prices are expected to slowly climb in the first quarter as the supply of the preferred US cracker feedstock is varied (ethane vs. propane) (ICIS, 2016). American refinery propene production is also expected to remain strong due to strong operating rates as a result of low gasoline prices (ICIS, 2016).

Supply in Northeast Asia is also expected to increase in Q1 2016 due to additionally capacity from SK Advanced's 600kT/year propane dehydrogenation unit expected to come on stream in March in South Korea (ICIS 2016). In China, propene consumption is expected to grow by 3.1 MT to 24.1 MT/year (Xiao, 2016). China already has 4 PDH plants with a total capacity of 2.1 million tonnes, with 2 more plants coming on this year (Xiao, 2016). Industry sources have said that Chinese PDH units have ben running at reduced capacity to prevent an oversupply of propene and "are expected to run around 70% of capacity this year in view of the projected demand for propylene" (Xiao, 2016). In Southeast Asia, IRPC is expected to run their 320 kT/year direct catalytic cracker on spec in Q1 (ICIS, 2016).

Propene Competition

A major source of propene is naphtha cracking and refinery cracking producing other products. However, the combination of reduced gasoline demand and the shift to lighter steam cracker feedstocks with lower propene yields has increased the amount of propene that is produced on purpose (Intratec, 2012). Current on purpose technologies include olefin metathesis, propane dehydrogenation, and methanol-to-olefins/methanol-to-propene, and fluid catalytic cracking (FCC). Olefin metathesis is a reversible reaction between ethylene and butenes in which double bonds are broken and then reformed to form propene (Intratec B, 2012). This process results in a 90 wt.% propane yield. Methanol-to-olefins/methanol-to-propene converts synthesis

gas to methanol and then convers the methanol to ethylene and propene. However, a large amount of methanol is required to make world scale propene plant. High severity FCC uses traditional FCC technology under severe conditions but only achieves conversions of around 25%.

There are five licensed technologies for propane dehydrogenation: CATOFIN from Lummus Technology, Oleflex from UOP, Fluidized Bed Dehydrogenation from Snamprogetti, STAR process from Thyssen Krupp Udhe, and PDH from Linde/BASF. The main differences between these technologies are the type of catalyst, regeneration methods, reactor design, and methods used to increase conversion. According to Intratec, there were at least 16 PDH units in operation with a capacity of 5260 kT/year of propene. Plans for 13 additional PDH units have been announced to increase capacity to 12,590 kT/year by the end of 2015 (Intratec). For the most part, most new units are based on the UOP technology (Gorte, 2016). If built now, our project would clearly be entering the market amidst a supply glut and tough economic conditions for propene producers. Producers are currently producing below capacity to avoid flooding the market.

Propane Market Overview

According to IFC International, "propane production is expected to continue to grow rapidly, keeping downward pressure on average propane prices relative to oil prices" (IFC, 2016). This is a positive sign for propene producers. If propane prices remain low, and propene prices rise to levels seen in 2014, this combination could allow for this project to make economic sense.

Preliminary Process Synthesis

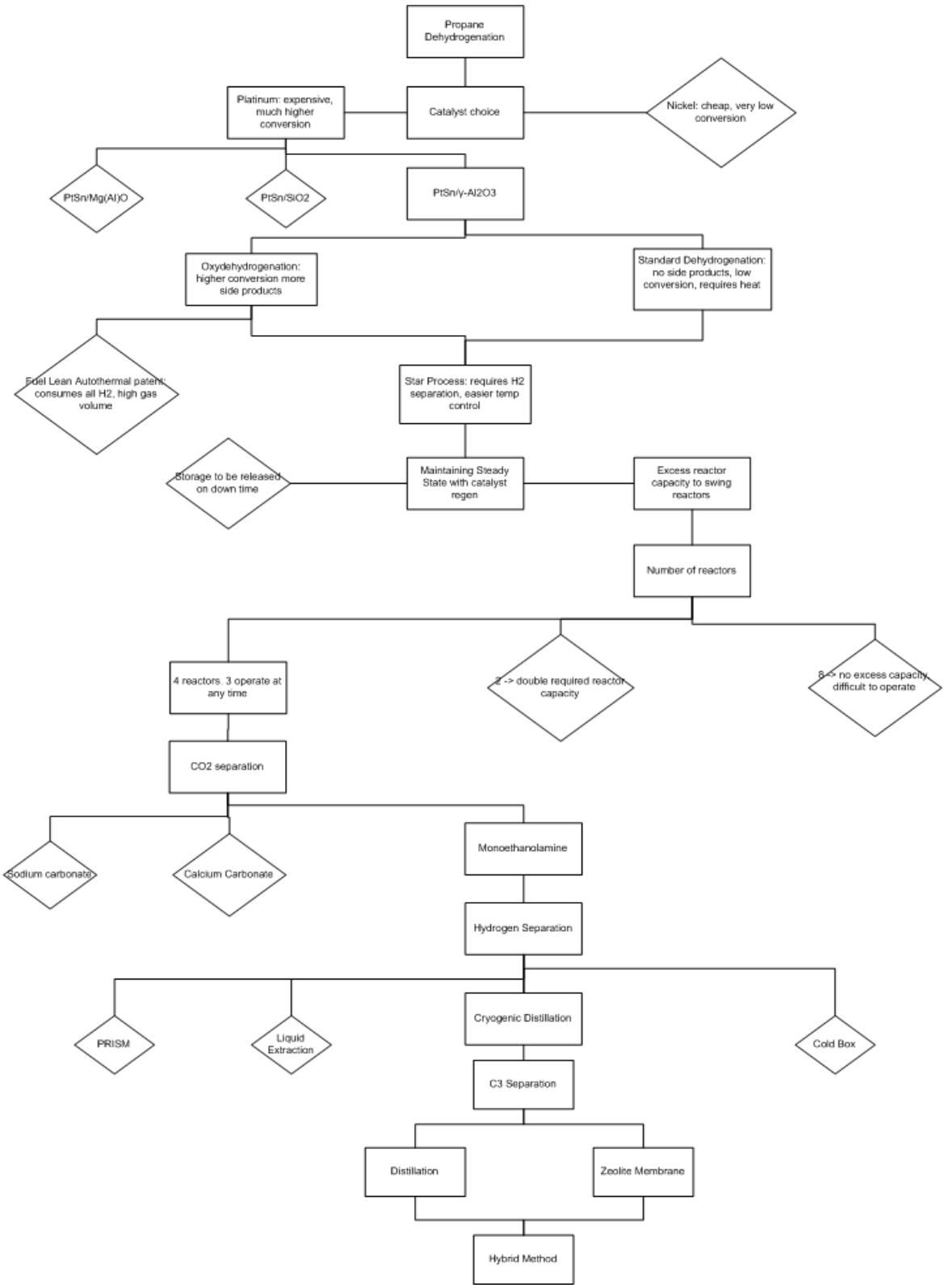

Figure 1 Process synthesis tree diagram showing developed decisions with rectangles and undeveloped decisions with diamonds

Process Block Diagram

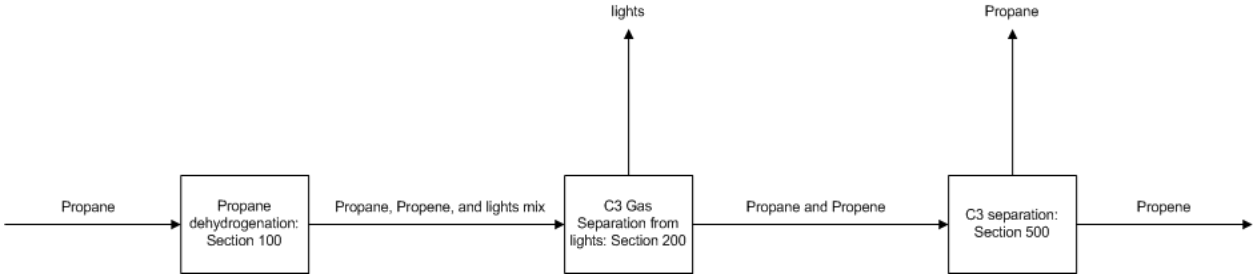

Figure 2 overall block diagram for producing propene from propane

Figure 2 shows an overall block diagram with the process steps for converting propane to propene. The first step is the reaction of propane to propene. Depending on the reaction process there could be a number of different products. No matter which reaction process is used there will be a need for separating propane and propene from hydrogen or carbon dioxide. Because full conversion of propane is impractical, the final step in the process will have to separate propane from the desired product.

Reactors

The dehydrogenation of propane is facilitated by a number of catalysts. The catalyst can be based on chromium, nickel, or platinum. Chromium and nickel are significantly cheaper than platinum, but can only achieve molar propane conversions of about 10% while platinum catalysts have demonstrated conversions of up to 50% under certain conditions (Herauville, 2012). The significant recycle volume associated with the low conversion of propane would require increased reactor and separation capital that made platinum the metal of choice. Patent US20030139637 and the STAR Process by UHDE have reported propane conversions of 50% using 0.2-0.6% platinum on a hydrotalcite support (ThyssenKrupp, 2014).

Propane can be converted to propylene through standard dehydrogenation in which propane is fed through a catalyst bed with an inert carrier or oxydehydrogenation in which oxygen is also fed to the reactor to consume hydrogen and push the conversion of propane further. In

standard propane dehydrogenation platinum catalyst can reach propane conversions of about 20-30% and propylene selectivities up to 100% at temperatures above 550 ^{o}C. This reaction is endothermic and requires heating to maintain reactor temperatures and achieve the desired conversion. In oxydehydrogenation propane can be reach conversions of 50% and the overall reaction is exothermic; depending on oxygen feeds the reactor may not need heating or cooling. Oxydehydrogenation also has side combustion reactions of propane and propylene with selectivities of about 3% (Rytter, 2003). Because of the large wide flammable limits of hydrogen, the concentration of oxygen to hydrogen has to be kept below 25% or above 96% by volume. Patent US20030139637 operates in the fuel lean regime which requires a large volume of gas heating and separations, but combusts all the hydrogen produced which removes the necessity of hydrogen separations and provides a large amount of heating for the reaction. The STAR Process operates in the fuel rich regime which does not consume all the hydrogen, but provides enough heat for the reaction. The STAR Process was chosen in favor of easier temperature control and avoiding increased capital costs to handle the larger volume of gases used by Patent US20030139637.

The catalyst has to be regenerated periodically due to deactivation from carbon deposition. In order for downstream operations to operate continuously the regeneration time has to be covered with excess reactor capacity and either storage or even more reactor capacity. The storage required decreases with increasing number of reactors, but fixed costs associated with the reactors and operational hazard increases with running more reactors. The excess reactor capacity required without storage also decreases with increasing number of reactors, but faces the same issues with increasing the number of reactors. Using 4 to 6 reactors as an optimum range of reactors, the capital required to store product is less expensive than increasing reactor capacity and dead time to forgo

storage. However, running reactors with excess capacity to avoid storage was chosen to avoid the safety risk associated with storing a large amount of gaseous fuel.

C3 Gas Separation from Lights

Once the choice of reactor was settled upon, oxydehydrogenation reactors, gas components to be separated out are water, carbon dioxide, carbon monoxide, hydrogen and lighter hydrocarbon components (lights). The water separation process is the first step because excess steam is fed to the reactor to decrease the vapor pressure of propane therefore water is removed first to decrease the overall size for the plant streams. The water is removed by simply cooling with cooling water and an adsorption column with 3A molecular sieves. The cooling water removes most of the water and the molecular sieve dries the gas by removing 95% of water present in the feed to the adsorption column.

Carbon dioxide is then removed next and various capture systems were considered. The systems considered were sodium carbonate, calcium carbonate and monoethanolamine (MEA) capture systems. The system decided upon was the MEA system because this capture system is purchased with its own utility provision system which saves on total utility cost for the process. The costing for the MEA system was estimated using the technoeconomic feasibility study performed on three different MEA capture systems with utilities. The process with the least utility cost and capital investment cost was decided upon (Hwang, 2012). The capture efficiency of the system is 94%.

Finally, prior to propane and propene separation, the other gas components are separated out. The options considered were a coldbox-pressure swing adsorption (PSA) system, cryogenic distillation, PRISM membrane separation. The coldbox-PSA system has the advantage of separating out hydrogen which could be sold as a byproduct. The hydrogen however is preferably

burnt as fuel to provide heating necessary for the process therefore does not require to be extracted using PSA. This separation is done by cryogenic distillation which separates out methane, ethane, ethene, hydrogen, carbon monoxide. This stream contents are burnt to provide heating as previously mentioned. The PRISM membrane separation only separates 85% of hydrogen and due to the 99.5% purity requirement of propene this process was not pursued.

Propane/Propene Separation

As was previously stated, three methods of propane/propene separation were considered for this report: using only a distillation column, using only a membrane, and using a hybrid configuration including elements of both previously mentioned designs. It was suggested that a hybrid separation system is the most optimal method of separation when compared to using only a distillation column or only a membrane (Benali, 2010). For this reason, the hybrid system was taken as the base-case and explored in the most detail in this report. The other designs were also explored and have their results summarized and are compared with the hybrid system in terms of economic viability.

When considering a hybrid separation system, the first major challenge was to decide whether the distillation column or the membrane would be used for the initial separation of propene from propane. Correspondingly, the configuration of the hybrid system had to be considered. A cost analysis and optimization report by Benali found that the most cost-effective configuration of a propane-propene hybrid separation system involves a distillation column performing the initial separation. The distillate of the column then undergoes further separation by passing through the membrane. Because Benali found this configuration to be the most cost effective in terms of capital and operating costs when used for C3 separation, it was pursued further by the group and chosen

as our base design which would be compared to the distillation only and membrane only separation systems.

Product Storage

It was decided that for the transportation of the propene product, tanker rail cars or tank capable of being transported by a truck would be used. These tanks are designed to handle pressures of 249 to 319 psi and temperatures of 14 to 149 F. Because of this, the permeate of the membrane must be liquefied and cooled to temperatures within the range of the tanker's specifications.

Assembly of Database

Aspen Simulation Specification

The overall process design was simulated in ASPEN Plus V8.8 software. The UNIQUAC property method which uses Ideal gas and Henry's law was used for the simulation except for the adsorption, absorption and membrane separations which were modelled in excel and their results hard coded into aspen as separator blocks.

The reactors were modelled using the RSTOIC which is a stoichiometric reactor which fractional conversions for all major and side reactions are specified. This model was used for the reformer and the oxyreactor. The distillation columns were initially modelled with DSTWU which provided insight on parameters such as minimum reflux ratio, feed tray location and distillate rate. The more rigorous model RADFRAC was then used with the known parameters in the final process design. The column parameters were then manipulated to produce desired results of separation using design specs.

The membrane separation process as mentioned before were modelled as simple separators where the component fraction in the permeate and retentate streams were manually entered. Similar process was applied to the adsorption and absorption processes. To simulate pressure drop across the membrane, turbines were placed on the permeate streams. Finally, for heat exchangers HEATER and HEATX models were applied.

Input Costs

The main utility inputs in the process are natural gas, electricity, cryogenic refrigeration, steam at various pressures, nitrogen gas as an inert, cooling and chilled water. The costs of these inputs were obtained from Process Design Principles, 3rd edition, by Seider, Seider, Levin and Windago.

The utility cost for the carbon dioxide capture system were scaled from technoeconomic feasibility study of capture systems (Hwang, 2012).

Raw material inputs for the continuous process are propane and oxygen. The price of propene was estimated by incorporating the price difference between propane and propene provided by our faculty advisor Dr. Raymond Gorte. The price of oxygen was estimated from oxygen production systems providing oxygen purity of 97% (Wilcox, 2005).

Table 1 Summary of material costs for the process design

Material	**Ratio (lb per lb propene)**	**Unit cost ($/lb)**
Propane	1.222	0.134
Oxygen	0.136	0.076
Propene	N/A	0.33

Safety and MSDS

Safety measures are discussed in the other consideration section. The major safety issue is flammability of the hydrocarbon components in the process design. Material Safety Data Sheets are compiled in Appendix C which further outline safety conditions.

Process Flow Diagram and Material Balances

Process Flow Diagrams

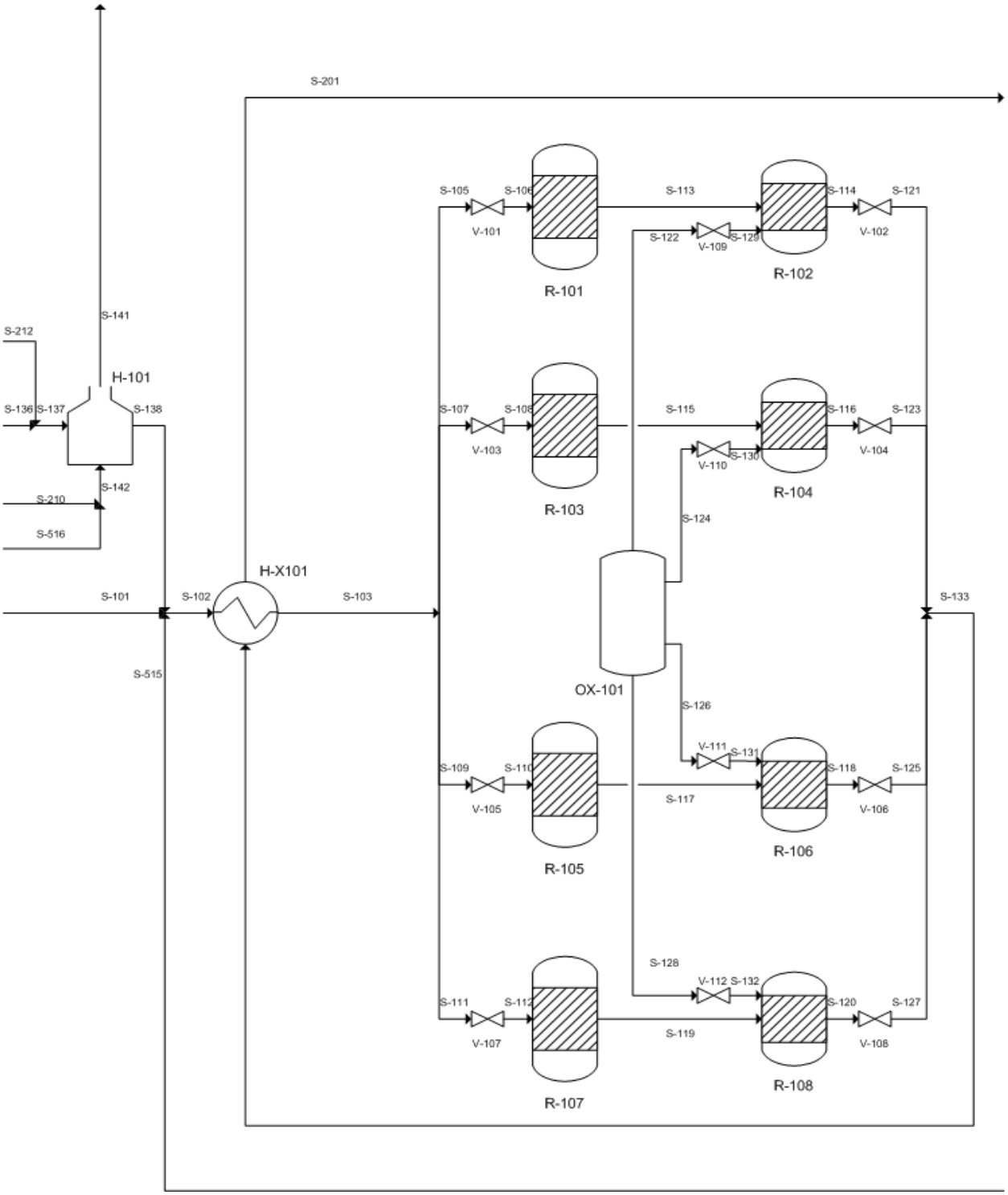

Figure 3 Schematic of reactor complex blocks and streams

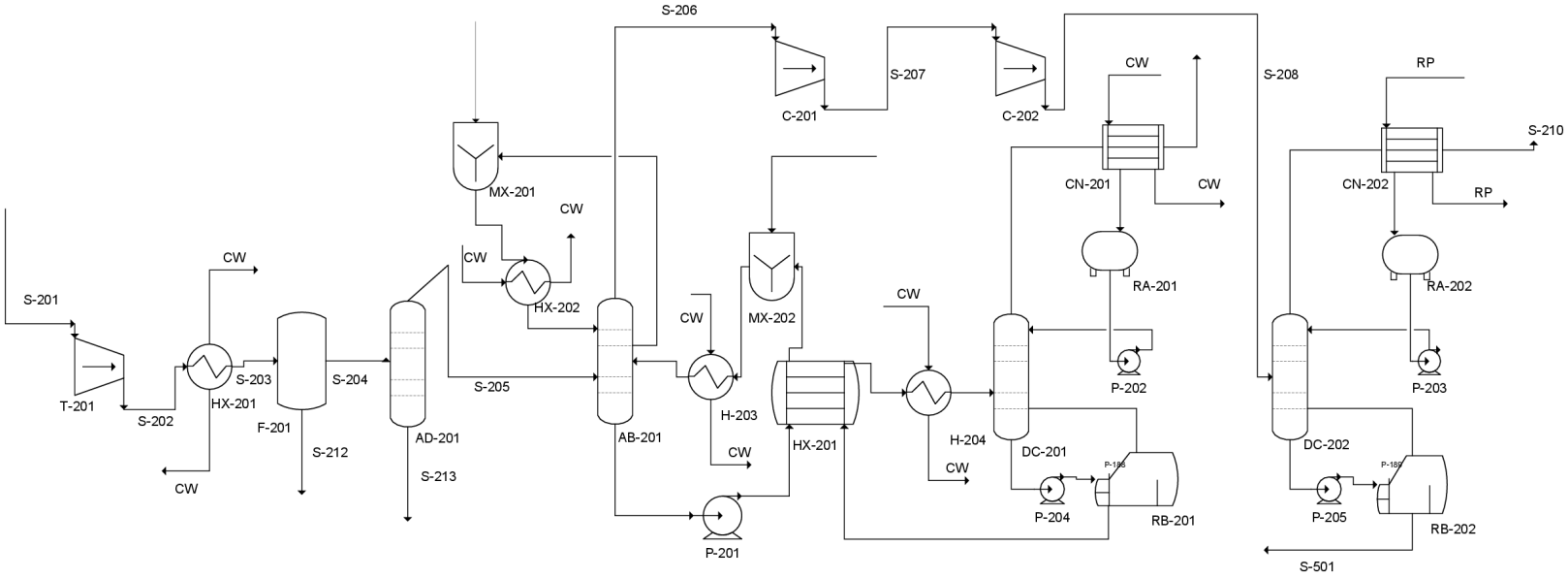

Figure 4 schematic of gas separation

KEY:

S-Stream
CW-Cold Water
RP-Refrigeration
T-Turbine
F-Free Water Collector
AD-Adsorption Column
MX-Represents Streams Mixing
AB-Absorption Column
HX-Heat Exchanger
P-Pump
RB-Reboiler
C-Compressor
DC-Distillation Column
RA-Reflux Accumulator
CN-Condensor

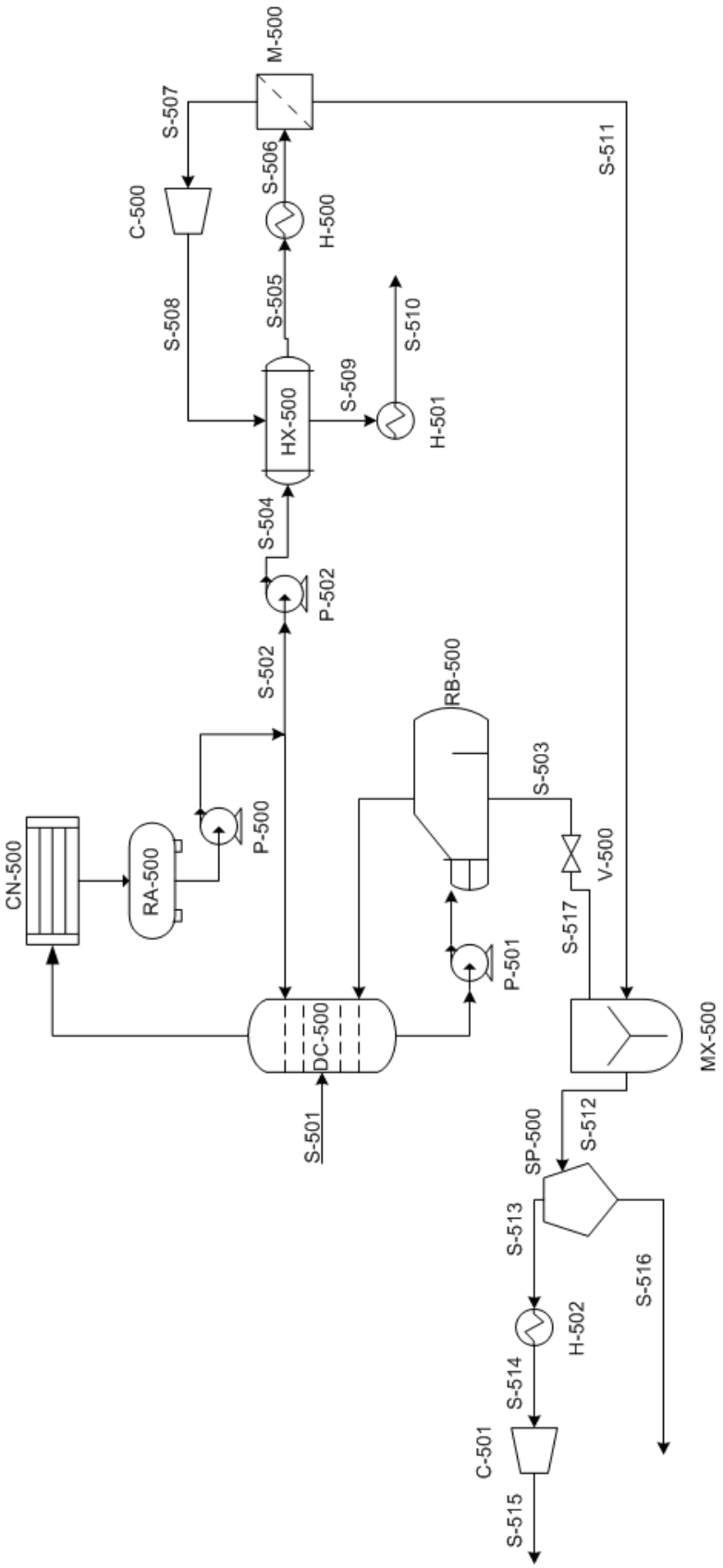

Figure 5 schematic of C3 separations using a hybrid system

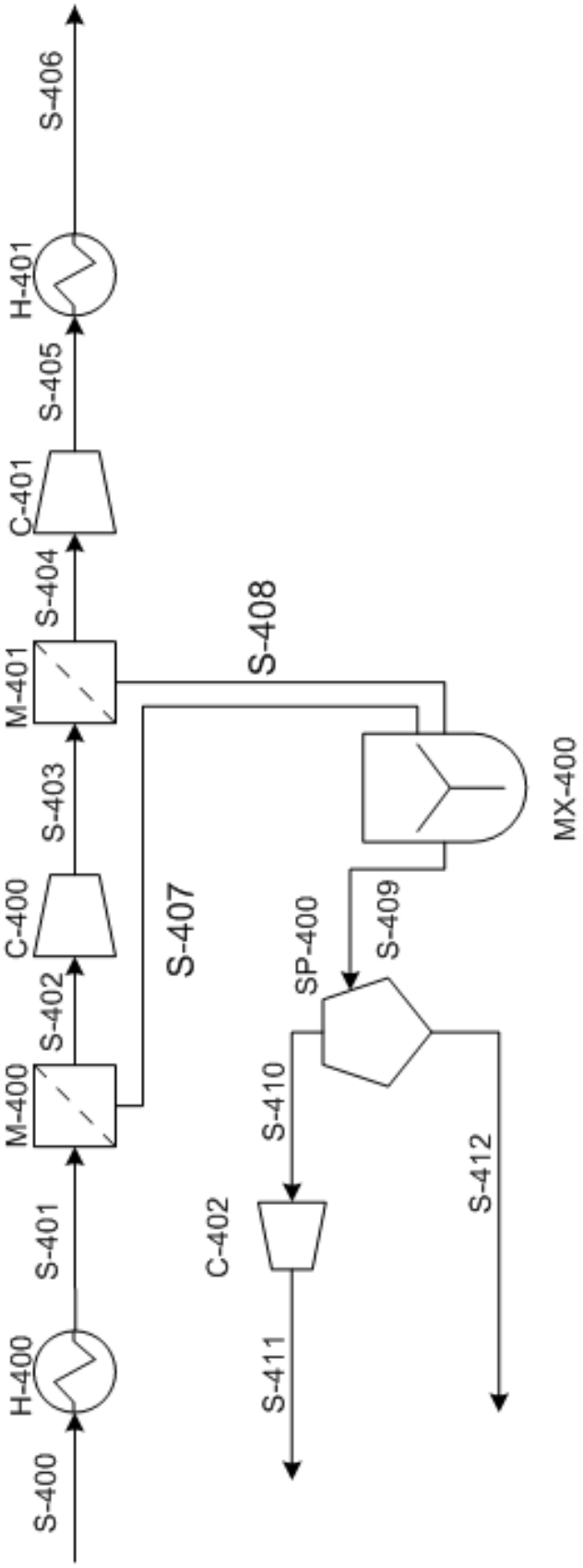

Figure 5 schematic of C3 separations using only membranes

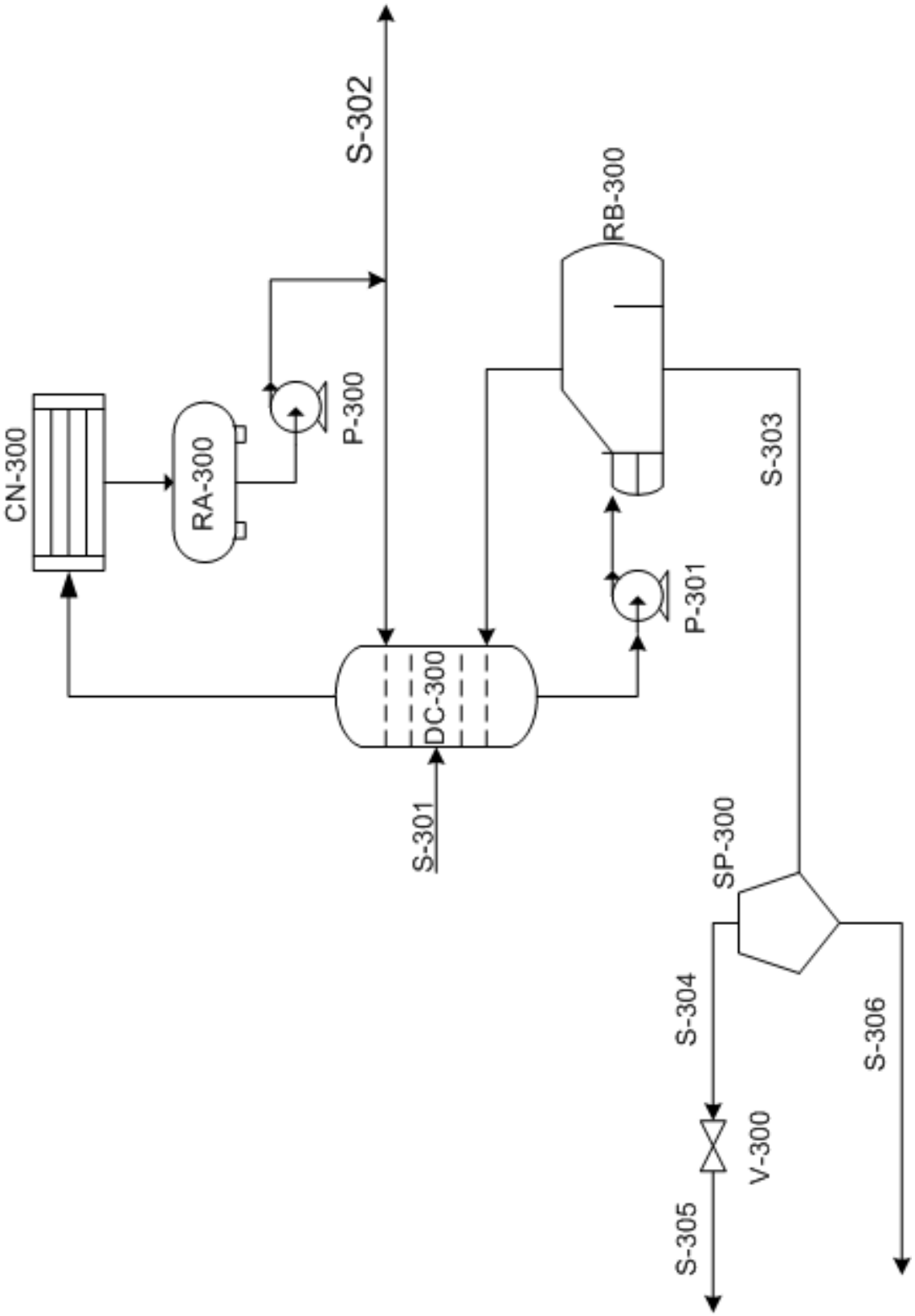

Figure 6 schematic of C3 separations using only a distillation column

Stream Tables

STREAM ID:		S-101	S-102	S-103	S-105	S-106	S-107	S-108	S-109	S-110	S-111	S-112
Temperature	F	77	288	1094	1094	1094	1094	1094	1094	1094	1094	1094
Pressure	PSIA	73	73	73	73	73	73	73	73	73	73	73
Total Mass Flow	LB/HR	215334	842487	842487	280829	280829	280829	280829	280829	280829	280829	280829
PROPANE	LB/HR	215334	406721	406721	135574	135574	135574	135574	135574	135574	135574	135574
PROPENE	LB/HR	0	20698	20698	6899	6899	6899	6899	6899	6899	6899	6899
HYDROGEN	LB/HR	0	0	0	0	0	0	0	0	0	0	0
OXYGEN	LB/HR	0	0	0	0	0	0	0	0	0	0	0
WATER	LB/HR	0	415058	415058	138353	138353	138353	138353	138353	138353	138353	138353
CO	LB/HR	0	0	0	0	0	0	0	0	0	0	0
CO2	LB/HR	0	2	2	1	1	1	1	1	1	1	1
METHANE	LB/HR	0	0	0	0	0	0	0	0	0	0	0
ETHANE	LB/HR	0	6	6	2	2	2	2	2	2	2	2
ETHENE	LB/HR	0	2	2	1	1	1	1	1	1	1	1
Enthalpy Flow	MMBTU/HR	-220	-2702	-2400	-800	-800	-800	-800	-800	-800	-800	-800

STREAM ID:		S-113	S-114	S-115	S-116	S-117	S-118	S-119	S-120	S-121	S-122	S-123
Temperature	F	1094	1211	1094	1211	1094	1211	1094	1211	1211	1094	1211
Pressure	PSIA	56	56	56	56	56	56	56	56	56	73	56
Total Mass Flow	LB/HR	280829	866281	280829	866281	280829	866281	280829	866281	866281	8000	866281
PROPANE	LB/HR	92953	213638	92953	213638	92953	213638	92953	213638	213638	0	213638
PROPENE	LB/HR	47394	201310	47394	201310	47394	201310	47394	201310	201310	0	201310
HYDROGEN	LB/HR	1937	6697	1937	6697	1937	6697	1937	6697	6697	0	6697
OXYGEN	LB/HR	0	0	0	0	0	0	0	0	0	8000	0
WATER	LB/HR	138353	436999	138353	436999	138353	436999	138353	436999	436999	0	436999
CO	LB/HR	0	1635	0	1635	0	1635	0	1635	1635	0	1635
CO2	LB/HR	1	5182	1	5182	1	5182	1	5182	5182	0	5182
METHANE	LB/HR	68	290	68	290	68	290	68	290	290	0	290
ETHANE	LB/HR	40	250	40	250	40	250	40	250	250	0	250
ETHENE	LB/HR	83	281	83	281	83	281	83	281	281	0	281
Enthalpy Flow	MMBTU/HR	-718	-2218	-718	-2218	-718	-2218	-718	-2218	-2218	1.93	-2218

STREAM ID:		S-124	S-125	S-126	S-127	S-128	S-129	S-130	S-131	S-132	S-133	S-136
Temperature	F	1094	1211	1094	1211	1094	1094	1094	1094	1094	1211	77
Pressure	PSIA	73	56	73	56	73	73	73	73	73	56	73
Total Mass Flow	LB/HR	8000	866281	8000	866281	8000	8000	8000	8000	8000	866281	33759
PROPANE	LB/HR	0	213638	0	213638	0	0	0	0	0	213638	0
PROPENE	LB/HR	0	201310	0	201310	0	0	0	0	0	201310	0
HYDROGEN	LB/HR	0	6697	0	6697	0	0	0	0	0	6697	0
OXYGEN	LB/HR	8000	0	8000	0	8000	8000	8000	8000	8000	0	0
WATER	LB/HR	0	436999	0	436999	0	0	0	0	0	436999	33759
CO	LB/HR	0	1635	0	1635	0	0	0	0	0	1635	0
CO2	LB/HR	0	5182	0	5182	0	0	0	0	0	5182	0
METHANE	LB/HR	0	290	0	290	0	0	0	0	0	290	0
ETHANE	LB/HR	0	250	0	250	0	0	0	0	0	250	0
ETHENE	LB/HR	0	281	0	281	0	0	0	0	0	281	0
Enthalpy Flow	MMBTU/HR	1.93	-2218	1.93	-2218	1.93	1.93	1.93	1.93	1.93	-2218	-230

STREAM ID:		S-137	S-138
Temperature	F	166	467
Pressure	PSIA	73	73
Total Mass Flow	LB/HR	417073	417073
PROPANE	LB/HR	0	0
PROPENE	LB/HR	0	0
HYDROGEN	LB/HR	0	0
OXYGEN	LB/HR	0	0
WATER	LB/HR	417073	417073
CO	LB/HR	0	0
CO2	LB/HR	0	0
METHANE	LB/HR	0	0
ETHANE	LB/HR	0	0
ETHENE	LB/HR	0	0
Enthalpy Flow	MMBTU/HR	-2807	-2312

STREAM ID:		S-201	S-202	S-203	S-204	S-205	S-206	S-207	S-208	S-210	S-212	S-213
Temperature	F	537	493	176	176	176	176	294	423	-96	176	176
Pressure	PSIA	53	35	35	35	30	25	100	300	270	35	30
Total Mass Flow	LB/HR	866281	866281	866281	440377	429832	424793	424793	424793	11637	425904	
PROPANE	LB/HR	213638	213638	213638	213638	213638	213638	213638	213638	58	0	0
PROPENE	LB/HR	201310	201310	201310	201310	201310	201310	201310	201310	2139	0	0
HYDROGEN	LB/HR	6697	6697	6697	6697	6697	6691	6691	6691	6691	0	0
OXYGEN	LB/HR	0	0	0	0	0	0	0	0	0	0	0
WATER	LB/HR	436999	436999	436999	11095	555	394	394	394	0	425904	10540
CO	LB/HR	1635	1635	1635	1635	1635	1635	1635	1635	1635	0	0
CO2	LB/HR	5182	5182	5182	5182	5182	311	311	311	308	0	0
METHANE	LB/HR	290	290	290	290	287	287	287	287	287	0	3
ETHANE	LB/HR	250	250	250	250	247	247	247	247	241	0	2
ETHENE	LB/HR	281	281	281	281	281	281	281	281	279	0	0
Enthalpy Flow	MMBTU/HR	-2521	-2543	-3063	-244	-184	-164	-138	-107	-8	-2863	-71

STREAM ID:		S501	S502	S503	S504	S505	S506	S507	S508	S509	S510	S511
Temperature	F	125	103	121	106	162	257	94	338	113	100	110
Pressure	PSIA	282	225	245	575	575	575	20	250	250	250	20
Total Mass Flow	LB/HR	407675	282388	125287	282388	282388	282388	177101	177101	177101	177101	105287
PROPANE	LB/HR	213575	89162	124413	89162	89162	89162	928	928	928	928	88234
PROPENE	LB/HR	193699	193216	484	193216	193216	193216	176173	176173	176173	176173	17042
HYDROGEN	LB/HR	0	0	0	0	0	0	0	0	0	0	0
OXYGEN	LB/HR	0	0	0	0	0	0	0	0	0	0	0
WATER	LB/HR	390	0	390	0	0	0	0	0	0	0	0
CO	LB/HR	0	0	0	0	0	0	0	0	0	0	0
CO2	LB/HR	3	3	0	3	3	3	0	0	0	0	3
METHANE	LB/HR	0	0	0	0	0	0	0	0	0	0	0
ETHANE	LB/HR	6	6	0	6	6	6	0	0	0	0	6
ETHENE	LB/HR	2	2	0	2	2	2	0	0	0	0	2
Enthalpy Flow	MMBTU/HR	-222	-85.6	-143	-84.8	-67.3	-29.5	36.6	55.4	37.9	13.3	-85.2

STREAM ID:		S512	S513	S514	S515	S516	S517
Temperature	F	-29	-29	72	181	-29	120
Pressure	PSIA	20	20	20	73	20	20
Total Mass Flow	LB/HR	230574	207517	207517	207517	23057	125287
PROPANE	LB/HR	212647	191382	191382	191382	21265	124413
PROPENE	LB/HR	17526	15773	15773	15773	1753	484
HYDROGEN	LB/HR	0	0	0	0	0	0
OXYGEN	LB/HR	0	0	0	0	0	0
WATER	LB/HR	390	351	351	351	39	390
CO	LB/HR	0	0	0	0	0	0
CO2	LB/HR	3	2	2	2	0	0
METHANE	LB/HR	0	0	0	0	0	0
ETHANE	LB/HR	6	6	6	6	1	0
ETHENE	LB/HR	2	2	2	2	0	0
Enthalpy Flow	MMBTU/HR	-228	-205	-194	-184	-22.7	-149

Process Description

The overall process was split into three sections: steam production, propane dehydrogenation, initial gas separation, and the final gas separation of propane and propene.

Propane Dehydrogenation

Water is fed to the boiler H-101 as shown in Figure 3 along with recycled water from downstream processes at 166 ^{o}F to produce 385471 lb/hr of steam at 73 psi. The steam is mixed with the reactor feed in a 2:1 molar ratio of steam to propane to keep the partial pressure of propane low and prevent carbon deposition on the catalyst which extends the length of time the catalyst can be used in reaction before regeneration. The steam is heated to a temperature of 467 ^{o}F to ensure that the vapor fraction of the reactor feed mixture remains at 1 after mixing with the propane feed. The heat duty on the boiler is 438 MMBTU/hr. Recycled hydrogen and propane are burned to supply the boiler with 383 MMBTU/hr of heat and the balance is covered with natural gas. The feed mixture is then sent through a heat exchanger with the reactor products to raise the feed mixture to reactor temperatures of 1094 ^{o}F.

After the propane feed and recycle have been mixed with steam and raised to reactor temperatures, the feed mixture is split into three equal streams and sent to the three reformers in operation. The propane reacts in the packed bed of 0.2-0.6% Pt-Sn/$ZnAl_2O_5$ catalyst at a temperature of 1094 ^{o}F and pressure of 73 psi. The feed has a residence time of 2 seconds and achieves 30% molar conversion of propane. Propane reacts according to the following reactions:

$$C_3H_8 \rightarrow C_3H_6 + H_2 \quad (1)$$

$$C_3H_8 \rightarrow C_2H_4 + CH_4 \quad (2)$$

$$C_3H_8 + H_2 \rightarrow C_2H_6 + CH_4 \quad (3)$$

$$C_3H_8 + 2\,H_2 \rightarrow\ 3\,CH_4 \quad (4)$$

$$CH_4 \rightarrow C + 2\,H_2 \quad (5)$$

After a reactor runs for six hours it is allotted an hour for shutdown and startup and an hour for catalyst regeneration. The catalyst is regenerated by first flushing the catalyst bed with pure nitrogen from the air separation unit to remove any large concentrations of fuel, and then air is fed through the catalyst bed at 1094 ^{o}F to burn off carbon deposition on the catalyst. With 4 reactors the 2-hour dead time is shifted from one reactor to the next to maintain a continuous operation of 3 reactors at any time.

Following the reformers, the products are fed to another reactor packed with the same catalyst that co feeds pure oxygen to react with hydrogen product from the reformer reactors and push the propane conversion. Some of the hydrocarbons in the oxydehydrogenation reactors react with oxygen to form carbon monoxide and carbon dioxide side products. The following reactions occur in the oxydehydrogenation of propane:

$$C_3H_8 + \frac{1}{2}\,O_2 \rightarrow\ C_3H_6 + H_2O \quad (6)$$

$$C_3H_8 + 5\,O_2 \rightarrow 3\,CO_2 + 4\,H_2O \quad (7)$$

$$C_3H_6 + \frac{9}{2}O_2 \rightarrow 3\,CO_2 + 3\,H_2O \quad (8)$$

$$CH_4 \rightarrow C + 2\,H_2 \quad (9)$$

$$2\,CO \rightarrow C + CO_2 \quad (10)$$

$$C + \frac{1}{2}O_2 \rightarrow CO \quad (11)$$

$$C + H_2O \rightarrow CO + H_2$$

$$C_3H_8 + 3\,H_2O \rightarrow 3\,CO + 7\,H_2$$

Propylene has a lower selectivity in the oxydehydrogenation reactors of 88% with a CO_x selectivity 10% and a small amount of light ends forming. The oxydehydrogenation produces carbon dioxide, which must be removed using MEA absorption later in the process, and carbon monoxide, which can be separated from propylene along with hydrogen. Even with the formation of these side products, oxydehydrogenation is favorable because consumption of hydrogen and increased conversion of propylene lower the separation duties of the hydrogen and the C3 separation columns. The oxydehydrogenation reactor operates adiabatically and the overall reaction system is exothermic causing the product stream to heat to about 1211 ^{o}F. This heat increase reduces the selectivity of propylene, but the increase in temperature offers a driving force for the reactor feed to increase to reformer temperatures during the product heat recovery.

C3 Gas Separation from Lights

This section is represented by Section 200 in Figure 2. Figure 4 provides more detail on the equipment for the C3 gas separation from lights section. The reactor effluent goes through turbine T-201 to reduce the pressure of the reactor effluent from 52.5 psi to 34.8 psi which is the required pressure for the adsorption column. The temperature decreases from 461 F to 419 F. The turbine produces recoverable power that is used in running compressors. After expansion the gas is cooled further using cooling water heat exchanger HX-201 cooling the reactor effluent from 419 F to 176 F. In this heat exchanger water precipitates out 97.3% of the water present in the reactor effluent. To save on utilities cost this water is recycled to the steam reformer. The cooler stream at lower pressure then goes through an adsorption column with 3A molecular sieves. The adsorption column separates out 95% of the remaining water. The water adsorption column goes through regeneration every 8hrs. The regeneration process begins with taking one of the adsorption columns offline after 80% loading of the 3A molecular sieves. Once loaded the other regenerated

column goes online. The regeneration process begins with 0.5 hours of nitrogen purging to remove any residual hydrocarbons in the column then hot air at 350 F to remove the loaded water for 6.5 hours. The column is then allowed to cool for 1 hour before being brought back online.

After water removal, carbon dioxide is removed from the reactor effluent. The monoethanolamine capture system has an efficiency of 94% (Hwang, 2012). The capture system is represented by AB-201 with the accompanied representative equipment shown in Figure 4. The gas steam then goes through a series compressive steps to increase the pressure from 25 psi to 300 psi for the cryogenic distillation. C-201 and C-202 achieve this pressure change. This pressure change is associated with a 176 F to 423 F. DC-202 separates out hydrogen, methane, ethane, ethane and the remaining carbon dioxide. The refrigeration cost of the column are high because cryogenic temperatures are necessary to separate out hydrogen. The separated out hydrogen is combusted in various heaters to provide necessary heating. The distillation column has 4 passes to reduce the diameter of the column and reduce cost.

Perfectly selective Pt-Sn Based Catalyst

During the design process information about the selectivity of a similar catalyst being 100% selective for the production of propene was introduced (Gorte, 2016). This would mean that gas separation of methane, ethane, ethane, carbon dioxide and carbon dioxide would be unnecessary. This would result in savings in the capital costs for the MEA capture system as well as the utilities for it. While there would be savings in not requiring the carbon dioxide capture system, cryogenic distillation would still be necessary for the removal of hydrogen from the hydrocarbon stream. The source also claims a lower conversion of 35% which would require overall greater recycle stream. The effect of lower selectivity would have to be investigated but one of the sure effects would be more energy intensive hydrogen separation due to the larger recycle stream. The removal of these

separation requirements could save money depending on how much cryogenic separation of hydrogen costs increase due to the reduction in single pass conversion.

Propane/Propene Separation

Hybrid System

The bottoms products from the hydrogen separation column is separated further, with the end goal to produce 99.5% pure, polymer grade propene which can then be sold. To do this, a hybrid separation process, which can be seen in Figure 4, is used which takes advantage of both multi-stage distillation columns and membranes to separate propene from the hydrocarbon mixture.

The bottoms product from the hydrogen separation column, DC-202, is comprised of 47.5% propene by mass. The desired product has a 99.5% propene composition. To achieve this, a distillation column and membrane are used is series. The distillation column, DC-500, produces a 68.4% propene by mass distillate at a temperature and pressure of 103 F and 225 psi respectively. Because of the expected size of the distillation column, 4 passes are used to limit the diameter of the column and consequently the cost. The temperature and pressure of this liquid distillate must be increased so that the stream is fed to the membrane as a vapor at a high enough pressure to account for the pressure drop through the membrane. The pressure of the liquid stream is increased to 575 psi using centrifugal pump, P-502. Heat exchanger, HX-500, increases the temperature of the stream to 162 F using heat from the final product stream. To vaporize the stream, heater H-500 is used to raise the temperature from 162 F to 257 F.

The high pressure, gas stream is then passed through membrane M-500. The membrane provides further purification of the stream, separating propene from the inlet stream. Propene passes through the membrane and exits in the permeate stream at a concentration of 99.5 percent. This product stream is at a temperature of 94 F and pressure of 20 psi. For transportation of the

propene product, it is desired that the stream be liquefied and stored at 100F and 250 psi. To do this, compressor C-500 is used to increase the stream's pressure from 20 to 250 psi. The exit temperature of the compressor is 338 F. Because the desired temperature is 100 F, the product stream exchanges some heat with the membrane's feed stream in heat exchanger H-500. The exit product stream temperature is 113 F. To achieve the desired 100 F, cooling water is used in heat exchanger H-501. The product stream is now at the desired composition, temperature, and pressure and can be safely stored and transported.

The bottoms product of the distillation column, DC-500, and the retentate of the membrane, M-500, can be collected and recycled to the reactor. The valve, V-500, decreases the pressure of the bottoms stream to 20 psi so that the bottoms and retentate streams are at the same pressure for mixing. After the liquid bottoms and vapor retentate are mixed using mixer MX-500 the stream is split using splitter, SP-500, with 90% of the stream being recycled and the other 10% being purged and burned for heat. The 90% that is being recycled is heated from -29 F to 77F using low pressure steam in heater H-502 to ensure the stream is entirely vapor. Compressor C-501 is then used to increase the pressure of the stream from 20 to 73 psi so that it can be mixed with the feed propane at identical pressures.

Distillation Column

The bottoms products from the hydrogen separation column is separated further, with the end goal to produce 99.5% pure, polymer grade propene which can then be sold. To do this, a multi-stage distillation column, which can be seen in Figure 6, is used to separate propene from the hydrocarbon mixture.

The bottoms product from the hydrogen separation column, DC-202, is comprised of 47.5% propene by mass. The desired product has a 99.5% propene composition. To achieve this, the bottoms product is fed to a distillation column. The distillation column, DC-300, produces a

99.5% propene by mass distillate at a temperature and pressure of 99 F and 225 psi respectively. Because of the expected size of the distillation column, 4 passes are used to limit the diameter of the column and consequently the cost.

The bottoms product of the distillation column, DC-300, is collected and recycled to the reactor. The stream is split using splitter, SP-500, with 90% of the stream being recycled and the other 10% being purged and burned for heat. The pressure of the 90% that is being recycled is decreased from 245 to 73 psi using the valve, V-300, so that it can be mixed with the feed propane at identical pressures.

Membrane System

The bottoms products from the hydrogen separation column is separated further, with the end goal to produce 99.5% pure, polymer grade propene which can then be sold. To do this, two membranes are used in series to separate propene from the hydrocarbon mixture, with the process being depicted in Figure 5.

The bottoms product from the hydrogen separation column, DC-202, is comprised of 47.5% propene by mass. The desired product has a 99.5% propene composition. To achieve this, the bottoms product is first fed to heater, H-400, which raises the stream temperature to 160 F and vaporizes the stream. The high pressure, gas stream is then passed through membrane M-400. This membrane provides an initial purification of the stream, separating propene from the inlet stream. Propene passes through the membrane and exits in the permeate stream at a concentration of 98.5 percent. This product stream is at a temperature of 3 F and pressure of 20 psi.

Before being fed to the second membrane, the pressure of the stream is increased to 290 psi using compressor, C-400, which also increases the temperature of the stream to 250 F. The stream is then fed through membrane M-401, which provides a final separation of propene from

propane. Propene passes through the membrane and exits in the permeate stream at a concentration of 99.5 percent. This product stream is at a temperature of 150 F and pressure of 20 psi.

For transportation of the propene product, it is desired that the stream be liquefied and stored at 100F and 250 psi. To do this, compressor C-500 is used to increase the stream's pressure from 20 to 250 psi. The exit temperature of the compressor is 403 F. Because the desired temperature is 100 F, cooling water is used in heat exchanger H-401. The product stream is now at the desired composition, temperature, and pressure and can be safely stored and transported.

The retentate of membranes, M-400 and M-401, can be collected and recycled to the reactor. After both vapor retentate streams are mixed using mixer MX-400, the stream is split using splitter SP-400 with 90% of the stream being recycled and the other 10% being purged and burned for heat. The pressure of the 90% that is being recycled is increased from 20 to 73 psi using compressor C-402 so that it can be mixed with the feed propane at identical pressures.

Energy Balance and Utility Requirements

To maximize efficiency, all streams were evaluated for their potential to heat or cool another process. In particular, the remaining H_2 that was removed (S-210, Figure 4) and the purge stream (S-516, Figure 5) have a significant amount of heat (7.88E8 BTU/hr) and are combusted to provide heat to other units in the process.

H_2 that is generated through the dehydrogenation process is reacted exothermically with the oxygen in the oxyreactors (R-102, R-104, R-106, R-108, Figure 3) to produce water. Since the oxyreactor is run adiabatically at 1094F, the reactor requires no utilities and heats the effluent streams (S-133 and associated streams, Figure 3) to 1211F. This increased temperature allows heat exchanger HX-101 to have a greater driving potential and thus drive more heat into the reformer feed stream (S-103).

R-101 and associated reactors run at 1094F and have an energy requirement of 4.05E7 BTU/hr each. This energy is supplied by the combustion of S-210. The steam fed to our reactor is recycled from our water adsorption unit in S-212 and boiled in H-101. The energy requirement of the fired heaters H-101, H-500 and H-502 is satisfied fully by the recovered energy from the streams S-210 and S-516. The distillation columns DC-202 and DC-500 heating requirement in the reboilers was also met by the combustion of S-210 and S-516 in fired heaters. The streams S-210 and S-516 provide a total of $7.88*10^8$ BTU/hr which as mentioned before covers most of the heating requirements for the process.

Compression of the gas prior to cryogenic distillation is the most electrical power intensive and requires a total of $1.67*10^4$ kW. This is necessary to reduce the temperature at which cryogenic distillation occurs. The compressors and pumps in the process are C-201, C-202, C-500, C-501 and P-500. In the process however power is generated through gas expansion

in the turbine T-201 which produces 5421 kW. This power is integrated into the process and used to run the compressors. Another electricity requirement is in running the blower whose power rating is 46.2 kW. The total electricity use for the process design $1.77*10^8$ kW/year.

Cryogenic distillation, DC-202 is the most energy intensive process requiring a total of 1.63 GJ/year of refrigeration. The refrigeration system is an ethylene based system providing refrigeration at -150 F. The top of the column is maintained at -96 F which is necessary for the separation of hydrogen.

The MEA capture system, AB-201 is accompanied with its own utility system which is overall cheaper than purchasing individual heating and cooling requirements. The capture system therefore only has the dollar amount necessary to run it and not the individual utilities which are provided in literature (Hwang, 2012).

The reactors (R-101 – R-108) and adsorption column AD-201 require a nitrogen purge during the regeneration cycles to purge out any hydrocarbons before the units are regenerated. The total nitrogen requirement is estimated to be about $4.27*10^6$ CF/year. It is highly likely that this number is an under estimate because the duration of the purging is likely to be longer than previously stated.

Other cooling requirements of the process are satisfied using cooling water and chilled water. The units H-201, DC-500 and H-501 require cooling water. The cooling water is purchased at 80 F and has an expected increase in temperature to 120 F Seider et, al. The total amount of cooling water necessary in the process is $4.12*10^{10}$ gal/year. The chilled water is necessary in the adsorption column to provide dry air for the regeneration of the adsorption column. The chilled air is purchased at 40 F and has an expected increase in temperature to 55F Seider et, al. The total cooling water energy necessary for the process is $2.68*10^5$ GJ/year.

HX-101 reduces the temperature of the oxyreactor effluent S-113 from 1211F to S-201's temperature of 461F. At the same time, the feed to the reformers is increased from 288F to 1094F, which is the operating temperature of reformer R-101 and associated reformers. The heat duty of HX-101 is 3.9E8 BTU/hr.

HX-101 reduces the temperature of the oxyreactor effluent S-113 from 1211F to S-201's temperature of 461F. At the same time, the feed to the reformers is increased from 288F to 1094F, which is the operating temperature of reformer R-101 and associated reformers. The heat duty of HX-101 is 3.9E8 BTU/hr.

HX-201 is the first exchanger in the process involving cooling water. This exchanger serves to cool the reactor effluent prior to separation processes in AD-201 and AB-201 as much as possible using cooling water. The hot stream (S- 202), with a flow rate of 866,281 lb/hr is cooled from 419 F to 176 F. The duty of the exchanger is 550MM BTU/hr.

HX-301 reduces the temperature of final product stream by heating the feed stream to the membrane by cooling the final product stream. The heat duty of HX-101 is $1*10^6$ BTU/hr.

The amounts and costs of the utilities required for this process are summarized in the Table 2 and 3 below.

Table 2 utility summaries

Utility	Unit	Ratio (per lb of propene)	Utility Cost ($ per unit)
Natural Gas	MMBTU	0.000381404	1.78
Electricity	kWh	0.110229795	0.07
Refrigeration (-150F)	GJ	0.001057012	33.2
MEA Capture System		6.47969E-10	1330000
Nitrogen	CF	0.002767269	0.0782
Cooling Water	gal	26.72223232	0.0001
Chilled Water	GJ	0.000173656	5
Total Weighted Average Utility Cost			**$0.048/lb propene**

Table 3 detailed utility requirements for all units

Utility Name	Process Unit	Quantity (MMBTU/yr)
Natural gas	H-101	2.62E+06
Natural gas	R-101	3.55E+05
Natural gas	R-103	3.55E+05
Natural gas	R-105	3.55E+05
Natural gas	R-107	3.55E+05
Natural gas	H-500	4.76E+05
Natural gas	DC-202	4.82E+05
Natural gas	DC-500	1.93E+06
Natural gas	H-502	9.20E+04
Natural gas	H-500	4.76E+05
Natural gas- recovered energy	S-210, S-516	-6.90E+06
	Total	5.89E+05

Utility Name	Process Unit	Quantity (kWh/yr)
Electricity	C-201	6.55E+07
Electricity	C-202	8.04E+07
Electricity- recovered energy	T-201	-5.42E+07
Electricity	AD-201	4.05E+05
Electricity	P-500	2.01E+06
Electricity	DC-500	2.91E+06
Electricity	C-500	4.84E+07
Electricity	C-501	2.47E+07
	Total	1.70E+08

Utility Name	Process Unit	Quantity (GJ/yr)
Refrigeration -150F	DC-202	1.63E+06
	Total	1.63E+06

Utility Name	Process Unit	Quantity
MEA Capture System	AD-202	1
	Total	1

Utility Name	Process Unit	Quantity (CF/yr)
Nitrogen Purge	AD-201	4.27E+06
	Total	4.27E+06

Utility Name	Process Unit	Quantity (MMBTU/yr)
Natural Gas	AD-201	1.54E+04
	Total	1.54E+04

Utility Name	Process Unit	Quantity (gal/yr)
Cooling Water	H-201	2.80E+10
	DC-500	1.20E+10
	H-501	1.30E+09
	Total	4.12E+10

Utility Name	Process Unit	Quantity (GJ/yr)
Chilled Water	AD-201	2.68E+05
	Total	2.68E+05

Equipment List and Unit Descriptions

Distillation Columns and Associated Equipment

DC-202 is a multistage distillation column that chiefly separates hydrogen, methane, ethane, ethane and carbon monoxide from propane and propene prior to hybrid separation. It contains 20 stages and fed (S-208) at the lowest tray, stage 19. The feed has a flow rate of 418,458 lb/hr. The molar reflux ratio of the column is 4.5. The condenser of the column operates at 270 psi with a 10 psi condenser pressure drop and 0.11 pressure drop for each stage. The distillation column bottoms S-501, a propane and propene rich stream flows at 406,818 lb/hr with conditions of 125 F and 282 psi. The distillation column overhead S-210, a lights rich stream flows at 11,640 lb/hr with conditions of -96 F and 270 psi. The height and diameter of the column were 48 ft and 23.1 ft, respectively. The total bare module cost of the column was $9.5 million with an estimated $57 million in utilities cost per year.

P-203 is a cast iron, centrifugal pump that is used to increase the pressure in the condenser. Designed to accommodate a flow rate of 34,403 gallons per minute and a head of 334.4 ft, the pump's bare module cost is $256,000. The pump requires 1496 kW of electricity which is a yearly utility cost of $917,000.

P-205 is a cast iron, centrifugal pump that is used to increase the pressure in the reboiler. Designed to accommodate a flow rate of 1,800 gallons per minute and a head of 493 ft, the pump's bare module cost is $82,000. The pump requires 78.3 kW of electricity which is a yearly utility cost of $48,000.

RA-202 is a reflux accumulator used in DC-500. The accumulator is a 45,990 ft^3 horizontal, carbon steel tank. The accumulator has a length of 61.6 feet and diameter of 30.8 feet

and is assumed to have a residence time of 5 minutes. The reflux accumulator's bare module cost is $295,000.

CN-202 is the condenser associated with the distillation column, DC-500. The condenser operates at 270 psi so that vapor from the top stage of the distillation column, DC-500, can be cooled using cooling water. CN-500 is made of carbon steel and has a length of 20 ft. With a duty of 146.12 MMBTU, the condenser has a surface area of 17,795 ft^2. This leads to an operating cost of $54,158,000 a year using cooling water and a bare module cost of $1,200,000.

RB-202 is the reboiler associated with the distillation column, DC-500. The reboiler is made of carbon steel and has a length of 20 ft. With a duty of 44.5 MMBTU, the reboiler has a surface area of 3,712 ft^2. The bare module cost of the reboiler is $2,100,000.

The multistage distillation column, DC-500, is used to provide an initial separation of propene from propane. It was found for propane-propene separation, that 90 was the most effective number of stages to be used in a distillation column (Benali, 2010). Trays in the column were spaced two feet apart. Because the materials being distilled offer no corrosive or reaction based concerns, carbon steel could be used as the construction material. The feed stream, S-501, enters the distillation column at the 45^{th} tray at a temperature of 125 F and pressure of 282 psi. This feed stream is 47.5% propene by mass and has a flow rate of 407,700 lb/hr. To obtain an acceptable separation of propene while keeping costs to a minimum, a reflux ratio of 5 was used. The condenser of the column operates at 225 psi with a 10 psi condenser pressure drop and 0.11 pressure drop for each stage. The bottoms product, S-503, has a flow rate of 125,300 lb/hr with the conditions of 121 F and 245 psi and is only .4% propene by mass. The column's distillate, S-502, is 68.4% propene by mass flowing at 282,400 lb/hr and is obtained at 103 F and 225 psi.

The final height of the column is 192 feet with a diameter of 29.9 feet. This results in a purchase cost of $10,875,000 and a bare module cost of $45,240,000.

P-500 is a cast iron, centrifugal pump that is used to increase the pressure in the condenser. Designed to accommodate a flow rate of 7,100 gallons per minute and a head of 337 ft, the pump's bare module cost is $79,600. The pump requires 308 kW of electricity which is a yearly utility cost of $189,000.

P-501 is a cast iron, centrifugal pump that is used to increase the pressure in the reboiler. Designed to accommodate a flow rate of 555 gallons per minute and a head of 493 ft, the pump's bare module cost is $18,900. The pump requires 24 kW of electricity which is a yearly utility cost of $14,800.

RA-500 is a reflux accumulator used in DC-500. The accumulator is a 9,470 ft^3 horizontal, carbon steel tank. The accumulator has a length of 36 feet and diameter of 18 feet and is assumed to have a residence time of 5 minutes. The reflux accumulator's bare module cost is $1,172,000.

CN-500 is the condenser associated with the distillation column, DC-500. The condenser operates at 225 psi so that vapor from the top stage of the distillation column, DC-500, can be cooled using cooling water. CN-500 is made of carbon steel and has a length of 20 ft. With a duty of 227 MMBTU, the condenser has a surface area of 27,600 ft^2. This leads to an operating cost of $1,196,000 a year using cooling water and a bare module cost of $1,066,000.

RB-500 is the reboiler associated with the distillation column, DC-500. The reboiler is made of carbon steel and has a length of 20 ft. With a duty of 220 MMBTU, the reboiler has a surface area of 18,400 ft^2. The bare module cost of the reboiler is $729,000.

MEA Absorption Column

AB-201 is an absorption column whose main purpose is to separate out carbon dioxide from the reactor effluent prior to propane and propene hybrid separation process. This is part of the system as mentioned will be purchased along with its own utility production system. The efficiency of the carbon dioxide separation is 94% of the carbon dioxide present in the feed stream is captured. The feed S-205 has a flowrate of 423,494 lb/hr with conditions 176F and 30 psi. The outlet stream conditions were assumed to be similar to the feed conditions with an allowable pressure drop of 5 psi through the column. The gas product stream therefore has a flowrate of 418,458 lb/hr and 176 F and 25 psi. The total bare module cost the capture system was estimated to be $3.17 million and operating costs of $1.3 million.

Water Absorption Column

AD-201 is an adsorption column which principally dries the reactor effluent stream prior to the gas separation process of propane and propene. The adsorption column dimensions are 35.7ft and 11.9ft in height and diameter respectively. The system requires two such columns a blower, chiller, heater, and heat exchanger. The packing for the column is 3A molecular sieves which allows the gas molecules other than water to pass through. The loading capacity of the column is 92% with a total cycle time of 8hrs. For the regeneration process hot air at 350 F is blown through for 7 hours and 1 hour allowed for transition and cooling of the packing. The total bare module cost of the system is $3.8 million with yearly utilities of $1.7 million.

Compressors

C-201 is a carbon steel electric motor drive centrifugal compressor. C-201 functions to compress the gas in S-206, prior to cryogenic distillation in DC-202. S-206 has a flow rate of

419,000 lb/hr and is at 176 F and 35 psi. The outlet stream S-207, comes out at 100 psi and 294 F. The compressor is isentropic and operates at 72% efficiency. A compressor rating of horsepower required is 10,030 hp. The compressor total bare module cost was estimated to be $7.1 million and $4.6 million in electricity utilities. The bare module cost incorporates intercooling costs for the compressor.

C-202 is a carbon steel electric motor drive centrifugal compressor. C-202 functions to compress the gas in S-207, prior to cryogenic distillation in DC-202. S-207 has a flow rate of 419,000 lb/hr and is at 294 F and 100 psi. The outlet stream S-208, comes out at 300 psi and 423 F. The compressor is isentropic and operates at 72% efficiency. A compressor rating of horsepower required is 12,000 hp. The compressor total bare module cost was estimated to be $8.5 million and $5.6 million in electricity utilities. The bare module cost incorporates intercooling costs for the compressor.

C-500 is a cast iron and stainless steel, centrifugal compressor that is used to increase the pressure of the product stream so that it can be liquefied and transported. The inlet stream, S-507, enters at 20 psi, 94 F, and a flow rate of 177,100 lb/hr. The outlet stream, S-508, has the same flow rate, an increased pressure of 250 psi, and a temperature of 338 F. The compressor requires 7410 HP and 5530 kW of electricity which is a yearly utility cost of $3,389,000. The compressor's bare module cost is $5,251,000.

C-501 is a cast iron and stainless steel, centrifugal compressor that is used to increase the pressure of the recycle stream so that it can be transported and mixed with the propane feed stream, S-103. The inlet stream, S-514, enters at 20 psi, 77 F, and a flow rate of 207,500 lb/hr. The outlet stream, S-515, has the same flow rate, an increased pressure of 78 psi, and a

temperature of 181 F. The compressor requires 3780 HP and 2820 kW of electricity which is a yearly utility cost of $1,727,000. The compressor's bare module cost is $3,062,000.

Turbine

T-201 is a turbine whose main function is to lower the pressure of stream S-201, which is at a temperature and pressure of 461 F and 52.5 psi respectively. This decrease in pressure is necessary for the functioning of the absorption and adsorption columns in the process. The output temperature and pressure of the turbine are 419 F and 35 psi. The turbine operates at 72% isentropic efficiency produces net work of 8,349 hp. The bare module cost of the turbine is $1.4 million.

Pumps

P-502 is a cast iron, centrifugal pump that is used to increase the pressure of the stream being fed to the membrane. The inlet stream, S-502, enters at 225 psi and a flow rate of 282,400 lb/hr. The outlet stream, S-504, has the same flow rate and an increased pressure of 575 psi. Designed to accommodate a flow rate of 1180 gallons per minute, the pump's bare module cost is $44,000. The pump requires 230 kW of electricity which is a yearly utility cost of $141,000.

Heat Exchangers

HX-101 is a shell and tube heat exchanger that recovers heat from the reactor products to heat the reactor feed. The reactor product is fed tube side at an inlet temperature 1211 ^{o}F at a flow rate of 824,000 lb/hr and released and an outlet temperature of 353^{o}F. The reactor feed is fed shell side at an inlet temperature of 279 ^{o}F at a flow rate of 807,000 lb/hr and released at an outlet temperature of 1094 ^{o}F. The heat exchanger recovers 442 MMBTU/hr which requires a surface area of 21,000 square ft. The tubes are composed of stainless steel to handle the high reactor product temperature. The total bare module cost of the heat exchanger is $1,313,000.

HX-201 is the first exchanger in the process involving cooling water. This exchanger serves to cool the reactor effluent prior to separation processes in AD-201 and AB-201 as much as possible using cooling water. The hot stream (S- 202), with a flow rate of 866,281 lb/hr is cooled from 419 F to 176 F. The duty of the exchanger is 550MM BTU/hr. This exchange is accomplished using five units with an area of 11,000 ft^2 each and the total bare module cost of $0.8 million. The cooling water utility for the system is $2.8 million per year.

The shell and tube heat exchanger heat exchanger, HX-500, is used to both increase the temperature of the stream fed to the membrane and to cool the product stream so that it can be transported. The cold inlet stream, S-504, enters at 106 F and a flow rate of 282,400 lb/hr and exits at the same flow rate at 162 F in stream S-505. The hot inlet stream, S-508, enters at 388 F and a flow rate of 177,100 lb/hr and exits at 113 F at the same flow rate, S-509. The heat duty is 17.55 MMBTU/hr which requires a surface area of 2,220 ft^2. The heat exchanger is made of carbon steel and has a bare module cost of $163,900.

Heaters

Heater H-101 is a steam boiler that produces high pressure steam to be fed with propane to the reactors to reduce coking of the catalyst which increases reactor run time. The boiler is fed 385,000 pounds of water per hour, most of which is recycled from downstream separations. The water is fed at 166 ^oF and boiled at a pressure of 73 psi and heated to a temperature of 467 ^oF. The duty on the boiler is 438 MMBTU/hr. Some of the boiler fuel cost is covered by recycled hydrogen, propane, and a small amount of propylene while the rest of the cost is covered by burning natural gas. The boiler is composed of stainless steel 304 and has a total bare module cost of $74,400,000.

The heater, H-500, is a fired heater that is used to vaporize the stream fed to the membrane. The cold inlet stream, S-505, enters at 162 F and a flow rate of 282,400 lb/hr and exits at the same flow rate and 257 F in stream S-506. The heater is made of carbon steel and has a bare module cost of $1,932,000. The heat duty is 54.33 MMBTU/hr and by burning recycled hydrogen, the utility cost is $847,000.

The heater, H-501, is used to liquefy the product stream so that it can be stored and transported. The hot inlet stream, S-509, enters at 113 F and a flow rate of 177,100 lb/hr and exits at the same flow rate and 100 F in stream S-510. The heat duty is 24.6 MMBTU/hr which requires a surface area of 2,470 ft^2. The heater is made of carbon steel and has a bare module cost of $177,800. Cooling water is used and the yearly utility cost is $129,500.

The heater, H-502, is a fired heater that is used to vaporize the recycle stream. The cold inlet stream, S-513, enters at -29 F and a flow rate of 207,500 lb/hr and exits at the same flow rate and 71.6 F in stream S-506. The heater is made of carbon steel and has a bare module cost of $727,000. The heat duty is 10.6 MMBTU/hr and by burning natural gas, the utility cost is $164,000.

Reactors

Reactors R-101, R-103, R-105, and R-107 are identical reactors that operate much like steam reformers. The function of the reactors is to continuously convert propane into propylene and hydrogen. 121,000 pounds of propylene are generated per hour by each reactor. Propane is fed with steam to the reactor at a temperature of 1094 ^oF and pressure of 73 psi. Steam is fed at a 2:1 steam to propane molar ratio to prevent coking of the catalyst and increase the activity of the catalyst before regeneration. Each reactor achieves a molar conversion of propane of 32% with a propene selectivity of 98% with side products of methane, ethylene, and ethane. The four

reactors are run in parallel with 3 reactors running at any given time while the fourth is regenerating catalyst. Each reactor runs for 6 hours and then is allowed 2 hours to shut down, start up, and regenerate the catalyst. The catalyst is regenerated by feeding air at 1094 ^{o}F for one hour to combust carbon deposition. Each reactor contains 326 tubes of 6-inch diameter to ensure heat transfer to the center of the tube. The tubes are 50 feet in length and are contained within a furnace burning 54 MMBTU/hr of natural gas to maintain a reactor temperature of 1094 ^{o}F with the endothermic conversion of propane to propylene. The tubes make up a total reactor volume of 3,200 cubic feet for each reactor. Each tube is composed of stainless steel 304 and has a wall thickness of 1.8 inches to ensure structural integrity at high temperature. The tubes are packed with 0.2-0.6% Pt-Sn/$ZnAl_2O_5$ catalyst with a weighted hourly space velocity of 2 hr^{-1} with propane. The catalyst packing has a void fraction of 0.7 which gives a pressure drop of 16.7 psi and residence time of 2 seconds. The reactor weighs 2,650,000 lbs and has total bare module cost of $104,419,000 including catalyst costs.

Reactors R-102, R-104, R-106, and R-108 are identical reactors that operate in series with the reformer reactors. These reactors are fed the product streams of the reformers along with 10% molar ratio of pure oxygen to propane to combust hydrogen and push the overall propane conversion to 49%. 17,800 pounds of propylene are generated per hour by each reactor. These reactors have lower propylene selectivity of 88% and produce carbon monoxide and carbon dioxide when propane and propylene combust with oxygen. Oxygen is dispersed evenly across the catalyst bed to achieve optimal conversion. The oxygen feed is assumed to be pure; if trace amounts of nitrogen are present, they will remain inert throughout the process until they are removed by the cryogenic distillation unit DC-202. These reactors have the same operating cycle as the reformers preceding them with 6 hours of run time and 2 hours of dead time with 3

reactors operating at any given time. Each reactor operates adiabatically with a feed temperature of 1094 ^{o}F and pressure of 56.3 psi. The overall system of reactions is exothermic producing 68 MMBTU/hr of heat which causes the products increase in temperature to 1211 ^{o}F and drop to a pressure of 52.5 psi. The reactor is a pressure vessel with 12 feet in diameter and 18 feet in length and a total volume of 2,178 cubic feet. The wall thickness is 0.625 inches of stainless steel 304 and each reactor weighs 27,600 pounds. The reactor is packed with 0.2-0.6% Pt-Sn/$ZnAl_2O_5$ catalyst with a weighted hourly space velocity of 2 hr^{-1} with propane. The bed has a void space of 0.7 which gives a residence time of 2 seconds. The total bare module cost of each reactor and its catalyst packing is $ 5,621,000.

Membrane

The membrane, M-500, is used to provide the final separation of propene from propane. With a selectivity of 35, permeance of 2.77 E-8, and pressure drop of 555 psi from feed to permeate, the required surface area of the membrane is 281,700 ft^2. The cost of the YSZ support necessary to manufacture the membrane costs $1,206,900. The cost of zinc nitrate hexahydrate is $1,002,500. The cost of 2-methylimidazole used in the manufacture of the membrane costs $27,457,000. This results in a membrane total cost of $30,873,000.

It should be noted that these cost estimates are based on prices obtained online for the purchase of small quantities of the raw materials required for manufacturing the membrane. These costing may be off by a factor of up to ten and more research is necessary to determine more accurate raw material pricing and manufacturing costs.

The feed stream, S-506, enters the membrane at a temperature of 257 F and pressure of 575 psi. This feed stream is 68.4% propene by mass and has a flow rate of 282,400 lb/hr. The retentate, S-511, has a flow rate of 105,300 lb/hr and is only 16% propene. The retentate is

obtained at 110 F and 20 psi. The permeate product stream, S-507, flowing at 177,100 lb/hr is 99.5% propene by mass and is obtained at 94 F and 20 psi.

Specification Sheets

Distillation Columns and Associated Equipment

DISTILLATION COLUMN			
Identification:	Item		Distillation Column
	Item No.		DC-202
	No. Required		1
Function:	Remove hydrogen, carbon monoxide and light components		
Operation:	Continuous		
Type:	N/A		
Stream ID	**Feed**	**Bottoms**	**Overhead**
	S-208	S-501	S-210
Flow rate (lb/hr)	418,458	406,818	11,640
Temperature (°F)	424	125	-96
Pressure (psia)	300	282	270
Composition (lb/hr)			
Propane	213,634	213,575	60
Propene	194,983	192,843	2,140
Hydrogen	6,691	0	6,690
Oxygen	0	0	0
Water	389	389	0
Carbon Monoxide	1,635	0	1,635
Carbon Dioxide	311	3	308
Methane	287	0	287
Ethane	247	6	241
Ethene	281	2	279
Design Data:	Tray Type:	Sieve	
	Packing Material:	Metal	
	Tray Spacing(ft):	2	
	Vendor:	KOCH	
	Column Height (ft):	48	
	Column Diameter (ft):	23.1	
	Material of Constructon:	Carbon Steel(SA-285 Grade C) & Stainless Steel	
	Number of Stages:	20	
	Feed Stage:	19	
	Reflux Ratio:	4.5	
	Boilup Ratio	1.12	
Cost of utilities/year:	Refrigeration -150°F	$	54,158,000.00
	Natural Gas	$	857,000.00
Purchase Cost:		$	1,460,000.00
Bare Module Cost:		$	6,000,000.00
Associated Costs:			
	Condenser:	$	1,200,000.00
	Reboiler System:	$	2,182,000.00
	Reflux Accumulator:	$	295,000.00
	Reflux Pump:	$	256,000.00
Total Bare Module Cost:		$	9,933,000.00
Comments:	Average cost of carbon steel and stailess steel used in costing factors		

REFLUX PUMP		
Identification:	P-203	
Function:	Pump the contents of the reflux accumulator back to DC-202	
Operation:	continuous	
Design Data:		
	Type:	Centrifugal
	Material:	Cast Iron
	Flow Rate (gpm):	34403
	Head (ft):	334.4
	Rating:	1496kW
Utilities Electricity	$	917,288.00
Total Bare Module Cost	$	256,000.00

REBOILER PUMP		
Identification:	P-205	
Function:	Increase pressure in the reboiler RB-202	
Operation:		
Design Data:		
	Type:	Centrifugal
	Material:	Cast Iron
	Flow Rate (gpm):	1800
	Head (ft):	493
	Rating:	24kW
Utilities Electricity	$	48,000.00
Total Bare Module Cost	$	82,000.00

REFLUX ACCUMULATOR			
Identification:	RA-202		
Function:	Acuumulate reflux in DC-202		
Operation:	continuous		
Design Data:			
	Type:		
	Material:		
	Diameter (ft):	30.8	
	Length (ft):	61.6	
	Capacity (ft^3):	45990	
	Residence Time (min) :	5	
Total Bare Module Cost		$	295,000.00

CONDENSER		
Identification:	CN-202	
Function:	To condense overhead contents of DC-202	
Operation:	Continuous	
Design Data:		
	Type:	Shell & Tube
	Subtype:	Fixed Head
	Material:	Carbon Steel
	Length (ft:)	20
	Area (ft^2):	17,795
	Condener Duty (MMBTU):	147
	Condenser Pressure (psia):	270
Utilities (cooling Water)	$	54,158,000.00
Total Bare Module Cost	$	1,200,000.00

REBOILER		
Identification:	RB-202	
Function:	Vaporize bottoms of DC-202	
Operation:	Continuous	
Design Data:		
	Type:	Shell &Tube
	Subtype:	Kettle Vaporizer
	Material:	Carbon Steel
	Length(ft):	20
	Area (ft^2)	3,712
	Reboiler Duty (MMBTU):	44.5
Total Bare Module Cost	$	2,100,000.00

DISTILLATION COLUMN

Identification:	Item		Distillation Column
	Item No.		DC-500
	No. Required		1
Function:	To provide an initial separation of propene from propane.		
Operation:	Continuous		
Type:	N/A		
Stream ID	**Feed**	**Bottoms**	**Overhead**
	S-501	S-503	S-502
Flow rate (lb/hr)	407675	125287	282388
Temperature (°F)	125	121	103
Pressure (psia)	282	245	225
Composition (lb/hr)			
Propane	213575	124413	89162.01
Propene	193699	484	193216
Hydrogen	0.000134751	0	0
Oxygen	0	0	0
Water	390	390	0
Carbon Monoxide	0.02	0	0.02
Carbon Dioxide	2.54	0	2.54
Methane	0.03	0	0.03
Ethane	6.3	0	6.3
Ethene	2	0	2
Design Data:	Column Diameter (ft):		30
	Material of Constructon:		Carbon Steel
	Number of Stages:		90
	Feed Stage:		45
	Reflux Ratio:		5
	Boilup Ratio		14.13
Cost of utilities/year:	Natural gas	$	3,435,000
	Cooling water	$	1,195,000.00
	Electricity	$	204,000.00
Purchase Cost:		$	10,875,000.00
Bare Module Cost:		$	45,240,000.00
Associated Costs:	Condenser:	$	1,066,000.00
	Reboiler:	$	7,458,867.00
	Reboiler Pump:	$	19,000.00
	Reflux Accumulator:	$	1,172,000.00
	Reflux Pump:	$	80,000.00
Total Bare Module Cost:		$	55,035,867.00
Comments:			

REFLUX PUMP		
Identification:	P-500	
Function:	Pump the contents of the reflux accumulator back to DC-500	
Operation:	continuous	
Design Data:		
	Type:	Centrifugal
	Material:	Cast Iron
	Flow Rate (gpm):	7086
	Head (ft):	337
	Rating:	308kW
Utilities Electricity	$	188,942.00
Total Bare Module Cost	$	79,630.00

REBOILER PUMP		
Identification:	P-501	
Function:	Increase pressure in the reboiler RB-500	
Operation:	Continuous	
Design Data:		
	Type:	Centrifugal
	Material:	Cast Iron
	Flow Rate (gpm):	555
	Head (ft):	493
	Rating:	24kW
Utilities Electricity	$ 14,788.00	
Total Bare Module Cost	$ 18,886.00	

REFLUX ACCUMULATOR			
Identification:	RA-500		
Function:	Acuumulate reflux in DC-500		
Operation:	continuous		
Design Data:			
	Type:		
	Material:		
	Diameter (ft):	18	
	Length (ft):	36	
	Capacity (ft^3):	9473	
	Residence Time (min) :	5	
Total Bare Module Cost		$	1,172,213.00

CONDENSER		
Identification:	CN-500	
Function:	To condense overhead contents of DC-500	
Operation:	Continuous	
Design Data:		
	Type:	Shell & Tube
	Subtype:	Fixed Head
	Material:	Carbon Steel
	Length (ft:)	20
	Area (ft^2):	27636
	Condener Duty (MMBTU):	227
	Condenser Pressure (psia):	225
Utilities (cooling Water)	$	1,195,520.00
Total Bare Module Cost	$	1,066,058.00

REBOILER		
Identification:	RB-500	
Function:	Vaporize bottoms of DC-500	
Operation:	Continuous	
Design Data:		
	Type:	Shell &Tube
	Subtype:	Kettle Vaporizer
	Material:	Carbon Steel
	Length(ft):	20
	Area (ft^2)	18363
	Reboiler Duty (MMBTU):	220
Total Bare Module Cost	$	729,080.00

Carbon Dioxide Capture System

CARBON DIOXIDE CAPTURE SYSTEM			
Identification:	Item		Composite
	Item No.		AB-201
	No. Required		1
Function:	Remove carbon dioxide from reactor effluent prior to C3 separeation		
Operation:	Continuous		
Type:	N/A		
Stream ID	**Feed**	**Bottoms**	**Overhead**
	S-205	S-218	S-205
Flow rate (lb/hr)	423494	N/A	418458
Temperature (°F)	176	N/A	176
Pressure (psia)	30	N/A	25
Composition (lb/hr)			
Propane	213634	N/A	213634
Propene	194983	N/A	194983
Hydrogen	6697	N/A	6690
Oxygen	0	N/A	0
Water	548	N/A	389
Carbon Monoxide	1635	N/A	1635
Carbon Dioxide	5181	N/A	311
Methane	287	N/A	287
Ethane	247	N/A	247
Ethene	281	N/A	281
Operating Costs(including utilities):		$	1,330,000.00
Total Bare Module Cost:		$	3,170,000.00
Comments:	Water amd MEA present in bottoms composition.		
	Design data provided Hwang, etc., 2013.		

Water Adsorption System

WATER ADSORPTION SYSTEM			
Identification:	Item		Adsorption Column
	Item No.		AD-201
	No. Required		2
Function:	Remove water from reactor effluent prior to C3 separeation		
Operation:	Continuous		
Type:	N/A		
Stream ID	**Feed**	**Bottoms**	**Overhead**
	S-204	S-213	S-205
Flow rate (lb/hr)	432420	422025	10395.36
Temperature (°F)	176	176	176
Pressure (psia)	34.8	30	30
Composition (lb/hr)			
Propane	213634	0	213,634
Propene	194983	0	194,983
Hydrogen	6697	0	6,697
Oxygen	0	0	0
Water	10967	10418	548
Carbon Monoxide	1635	0	1,635
Carbon Dioxide	5181	0	5,181
Methane	290	2.9	287
Ethane	250	2.5	247
Ethene	281	0	281
Design Data:	Packing Type:	Molecular Sieve	
	Packing Material:	3A Molecular Sieve	
	Packing Weight (lb):	250,000	
	Column Height (ft):	35.70	
	Column Diameter (ft):	11.9	
	Material of Constructon:	Carbon Steel	
	Total cycle time (hr):	8	
	Regeneration time (hr):	7	
	Transition Time (hr):	1	
Cost of utilities/year:	Electricity	$	28,350.00
	Nitrogen (purge)	$	333,000.00
	Chilled Water	$	1,340,000.00
	Natural Gas	$	27,700.00
Purchase Cost:		$	209,000.00
Bare Module Cost:		$	869,440.00
Associated Costs:	Packing:	$	70,000.00
	Blower:	$	125,190.00
	Chiller:	$	109,140.00
	Heater:	$	1,000,000.00
	Heat Exchanger:	$	738,000.00
Total Bare Module Cost:		$	3,870,000.00
Comments:	Nitrogen utility to purge hydrocarbons fromcolumns		
	Cost is for both columns and associated equipment		

Compressors

COMPRESSOR			
Identification:	Item		Compressor
	Item No.		C-201
	No. Required		1
Function:	Compress air before cryogenic distillation		
Operation:	Continuous		
Type:	First compressor in two stage compressor process		
Stream ID	**Stream In**	**Stream Out**	
	S-206	S-207	
Air Flow Rate (lb/hr)	418458	418458	
Temperature (°F)	176	294	
Pressure (psi)	35	100	
Design Data:	Construction Material:	Carbon Steel	
	Consumed (Hp):	10,030	
	Drive Type:	Elecric Motor Drice	
	Total Cooling Duty (BTU/hr):	$2.5*10^7$	
Cost of utilities/year:	Electricity	$	4,586,349.00
Purchase Cost:		$	3,100,000.00
Bare Module Cost:		$	7,130,000.00
Comments:	Bare Module cost includes interstage cooling using recycled chilled water		

COMPRESSOR			
Identification:	Item		Compressor
	Item No.		C-202
	No. Required		1
Function:	Compress air before cryogenic distillation		
Operation:	Continuous		
Type:	Second compressor in two stage compressor process		
Stream ID	**Stream In**	**Stream Out**	
	S-207	S-208	
Air Flow Rate (lb/hr)	418458	418458	
Temperature (°F)	294	423	
Pressure (psi)	100	300	
Design Data:	Construction Material:	Carbon Steel	
	Consumed (Hp):	12,321	
	Drive Type:	Elecric Motor Drice	
	Total Cooling Duty (BTU/hr):	$4.1*10^7$	
Cost of utilities/year:	Electricity	$	5,628,440.00
Purchase Cost:		$	3,700,000.00
Bare Module Cost:		$	8,510,000.00
Comments:	Bare Module cost includes interstage cooling using recycled chilled water		

COMPRESSOR		
Identification:	Item	Centrifugal Compressor
	Item No.	C-500
	No. Required	1
Function:	To compress the propene product.	
Operation:	Continuous	
Type:	N/A	
Stream ID	**Stream In**	**Stream Out**
	S-507	S-508
Air Flow Rate (lb/hr)	177101	177101
Temperature (°F)	93.67574	338.2659
Pressure (psi)	20	250
Design Data:	Construction Material:	Cast Iron/Carbon-Steel
	Power (Hp):	7,411
	Drive Type:	Electric Motor Drive
Cost of utilities/year:	Electricity	$ 3,388,000.00
Purchase Cost:		$ 2,442,000.00
Bare Module Cost:		$ 5,251,000.00
Comments:		

COMPRESSOR			
Identification:	Item		Centrifugal Compressor
	Item No.		C-501
	No. Required		1
Function:	To increase the pressure of the recycle stream.		
Operation:	Continuous		
Type:	N/A		
Stream ID	**Stream In**	**Stream Out**	
	S-514	S-515	
Air Flow Rate (lb/hr)	207517	207517	
Temperature (°F)	71.6	180.7543	
Pressure (psi)	20	72.51887	
Design Data:	Construction Material:	Cast Iron/Carbon-Steel	
	Consumed/Produced power (Hp)	3776	
	Drive Type:	Electric Motor Drive	
Cost of utilities/year:	Electricity	$	1,726,000.00
Purchase Cost:		$	1,424,000.00
Bare Module Cost:		$	3,062,000.00
Comments:			

Turbine

TURBINE		
Identification:	Item	Turbine
	Item No.	T-201
	No. Required	1
Function:	Lower pressure prior to water removal	
Operation:	Continuous	
Type:	Single stage turbine with recoverable power	
Stream ID	**Stream In**	**Stream Out**
	S-201	S-202
Air Flow Rate (lb/hr)	824709	824709
Temperature (°F)	461	419
Pressure (psi)	52.5	35
Design Data:	Construction Material:	Carbon Steel
	Produced power (Hp):	8,349
Purchase Cost:		$ 795,000.00
Bare Module Cost:		$ 1,431,000.00

Pumps

PUMP			
Identification	Item		Centrifugal Pump
	Item No.		P-500
	No. Required		1
Function	To increase the pressure of the stream fed to the membrane.		
Operation	Continuous		
Type	Pump		
Stream ID	**Stream In**	**Stream Out**	
	S-502	S-504	
Flow Rate (lb/hr)	282388	282388	
Inlet Temperature (ºF)	103	106	
Pressure (psia)	225	575	
Design Data:	Flow Rate (gpm)	1181	
	Construction materials	Cast Iron	
Cost of utilities/year:	Electricity	$	141,000.00
Purchase Cost:		$	13,300.00
Bare Module Cost:		$	44,000.00
Total Bare Module Cost:		$	44,000.00
Comments:			

Heat Exchangers

HEAT EXCHANGER			
Identification	Item		Heat exchanger
	Item No.		HX-101
	No. Required		1
Function	Heats feed to the reformer using oxyreactor products		
Operation	Continuous		
Type	Floating head, shell and tube		
Stream ID		**Tube Side**	**Shell Side**
Stream In		S-133	S-102
Stream Out		S-201	S-103
Flow Rate (lb/hr)		824709	806901
Inlet Temperature (ºF)		1211	279
Outlet Temperature (ºF)		353	1094
Design Data:	Surface area (ft^2)		21000
	LMTD (ºF)		141
	Heat duty (MMBTU/hr)		442.436
	Construction materials		Stainless steel/stainless steel
Purchase Cost:			$ 210,000.00
Bare Module Cost:			$ 1,313,000.00
Comments:	Costed by combining a 12000sqft and 9000sqft heat exchangers		

HEAT EXCHANGER

Identification	Item		Heat exchanger
	Item No.		HX-201
	No. Required		5
Function	Cool the products from the reactor complex		
Operation	Continuous		
Type	Floating head, shell and tube		
Stream ID		**Tube Side**	**Shell Side**
Flow Rate (lb/hr)		866281	CW
Inlet Temperature (ºF)		419	80
Outlet Temperature (ºF)		176	120
Design Data:	Surface area (ft^2)		11000
	Cooling Duty (MMBTU/hr)		550
	Construction materials		Carbon Steel
Cost of utilities/year:	Cooling Water		$ 2,799,524.00
Purchase Cost:			$ 230,000.00
Total Bare Module Cost:			$ 738,300.00

HEAT EXCHANGER

Identification	Item		Heat exchanger
	Item No.		HX-500
	No. Required		1
Function	To increase the temperature of the stream fed to the membrane.		
Operation	Continuous		
Type	Floating head, shell and tube		
Stream ID	**Tube Side**	**Shell Side**	
Stream In	S-504	S-508	
Stream Out	S-505	S-509	
Flow Rate (lb/hr)	282388	177101	
Inlet Temperature (ºF)	106	338	
Outlet Temperature (ºF)	162	113	
Design Data:	Surface area (ft^2)	2223	
	LMTD (ºF)	52.7	
	Heat duty (MMBTU/hr)	17.55	
	Construction materials	Carbon Steel	
Purchase Cost:		$	52,000.00
Bare Module Cost:		$	164,000.00
Comments:			

Heaters

STEAM BOILER			
Identification	Item		Heater
	Item No.		H-101
	No. Required		1
Function	Produces steam to be fed to the reformer		
Operation	Continuous		
Type	Fired heater		
Stream ID	**Inlet**	**Outlet**	
	S-137	S-138	
Flow Rate (lb/hr)	385471	385471	
Temperature (ºF)	166	467	
Pressure (psi)	73	73	
Design Data:	Heat duty (MMBTU/hr)	438.439	
	Construction materials	Stainless steel 304	
Cost of utilities/year:	Natural gas	$	6,134,831.00
Purchase Cost:		$	40,000,000.00
Bare Module Cost:		$	74,400,000.00
Total Bare Module Cost:		$	74,400,000.00
Comments:	Fed by fuel gas in S-142		

HEATER			
Identification	Item		Heater
	Item No.		H-500
	No. Required		1
Function	To vaporize the stream fed to the membrane.		
Operation	Continuous		
Type	Fired heater		
Stream ID		**Stream In**	**Stream Out**
		S-505	S-506
Flow Rate (lb/hr)		282388	282388
Temperature (ºF)		162	257
Pressure (psia)		575	575
Design Data:		Heat duty (MMBTU/hr)	54.33
		Construction materials	Carbon Steel
Cost of utilities/year:		Recycled hydrogen	$ 847,000.00
Purchase Cost:			$ 610,000.00
Bare Module Cost:			$ 1,932,000.00
Comments:			

HEATER			
Identification	Item		Heat exchanger
	Item No.		H-501
	No. Required		1
Function	To liquify the propene product.		
Operation	Continuous		
Type			
Stream ID	**Stream In**	**Stream Out**	
	S-509	S-510	
Flow Rate (lb/hr)	177101	177101	
Temperature (ºF)	113	100	
Pressure (psia)	250	250	
Design Data:	Heat duty (MMBTU/hr)		24.566
	Construction materials		
Cost of utilities/year:	Cooling Water	$	130,000.00
	Construction materials		Carbon Steel
Purchase Cost:		$	56,000.00
Bare Module Cost:		$	178,000.00
Comments:			

HEATER			
Identification	Item		Heater
	Item No.		H-502
	No. Required		1
Function	To vaporize the recycle stream.		
Operation	Continuous		
Type	Fired heater		
Stream ID		**Stream In**	**Stream Out**
		S-513	S-514
Flow Rate (lb/hr)		207517	207517
Temperature (ºF)		-29	72
Pressure (psia)		20	20
Design Data:		Heat duty (MMBTU/hr)	10.497
		Construction materials	Carbon Steel
Cost of utilities/year:		Natural gas	$ 164,000.00
Purchase Cost:			$ 332,000.00
Bare Module Cost:			$ 727,000.00
Comments:			

Reactors

REFORMER					
Identification	Item			Vertical Vessel	
	Item No.			R-101, R-103, R-105, R-107	
	No. Required			4	
Function	Produces propene through propane dehydrogenation				
Operation	Continuous				
Type	N/A				
Stream ID	**Inlet**		**Outlet**		
	S-106		S-113		
Temperature (ºF)	1094		1094		
Pressure (psi)	73		56.3		
Flow rate (lb/hr)	806901		806901		
Composition (lb/hr)					
Propane	406720		278858		
Propene	13936		135420		
Hydrogen	0		5812		
Oxygen	0		0		
Water	386235		386235		
Carbon monoxide	0.01		0.01		
Carbon dioxide	2.25		2.25		
Methane	0.03		203		
Ethane	5.56		120		
Ethene	1.76		250		
Design Data:	Number of tubes:	326	Catalyst:	.2-.6%Pt-Sn/ZnAl2O5	
	Tube diameter (ft):	0.5	Propane conversion:	0.32	
	Tube length (ft):	50	Propylene selectivity	0.976	
	Total volume (ft^3):	3203	C1-C2 selectivity:	0.024	
	Wall thickness (in):	1.8	COx selectivity:	0	
	Vessel weight (lb):	2,649,700	Particle diameter (in)	0.1	
	Velocity (ft/s):	32	Bulk density (g/cm^3):	0.336	
	Residence time (sec)	2	Catalyst weight (lb):	67655	
	WHSV (1/hr)	2	Regeneration time (hr	1	
	Void fraction:	0.7	Duty (MMBTU/hr)	53.99	
	Pressure drop (psi):	16.7	Contruction material:	Stainless Steel 304	
Cost of utilities/year:	Natural gas		$	2,525,000.00	
Purchase Cost:			$	25,458,000.00	
Bare Module Cost:			$	97,089,000.00	
Associated Costs:	Catalyst		$	7,330,000.00	
Total Bare Module Cost:			$	104,419,000.00	
Comments:	R-103, R-105, R-107 are identical to R-101				

OXYREACTOR

Identification	Item	Vertical Vessel
	Item No.	R-102
	No. Required	4
Function	Produces propene through propane oxydehydrogenation	
Operation	Continuous	
Type	N/A	

Stream ID	**Inlet** S-113	**Inlet** S-129	**Outlet** S-114
Temperature (°F)	1094	1094	1211
Pressure (psi)	56.3	56.3	52.5
Flow rate (lb/hr)	806901	23999	824709
Composition (lb/hr)			
Propane	278858	0	213634
Propene	135420	0	194983
Hydrogen	5812	0	6697
Oxygen	0	23999	0
Water	386235	0	401758
Carbon monoxide	0.01	0	1635
Carbon dioxide	2.25	0	5181
Methane	203	0	290
Ethane	120	0	250
Ethene	250	0	281

Design Data:				
	Reactor diameter (ft):	12	Catalyst:	.2-.6%Pt-Sn/ZnAl2O5
	Reactor length (ft):	18	Propane conversion:	0.25
	Total volume (ft^3):	2178	Propylene selectivity:	0.877
	Wall thickness (in):	0.625	C1-C2 selectivity:	0.015
	Vessel weight (lb):	27,600	COx selectivity:	0.108
	Velocity (ft/s):	20	Particle diameter (in):	0.1
	Residence time (sec):	2	Bulk density (g/cm^3):	0.336
	WHSV (1/hr)	2	Catalyst weight (lb):	46006
	Void fraction:	0.7	Regeneration time (hr	1
	Pressure drop (psi):	3.8	Duty (MMBTU/hr)	-17.086
	Construction material:	Stainless Steel 304		

Cost of utilities/year:		$	-
Purchase Cost:		$	154,000.00
Bare Module Cost:		$	638,000.00
Associated Costs:	Catalyst	$	4,983,000.00
Total Bare Module Cost:		$	5,621,000.00
Comments:	R-104, R-106, R-108 are identical to R-102		

Membrane

MEMBRANE			
Identification:	Item		ZIF-8 Membrane
	Item No.		M-500
	No. Required		1
Function:	To provide an final separation of propene from propane.		
Operation:	Continuous		
Type:	N/A		
Stream ID	**Feed**	**Permeate**	**Retentate**
	S-506	S-507	S-511
Flow rate (lb/hr)	282388	177101	105287
Temperature (°F)	257	94	110
Pressure (psia)	575	20	20
Composition (lb/hr)			
Propane	90036	928	89108
Propene	4592	176174	16207
Design Data:	Selectivity (propylene/propane		35
	Propene permeance (mol/m^2/Pa)		2.77E-08
	Area (ft^2)		281692
	Pressure drop: feed to permeate		555
	Pressure drop: feed to retentate		555
Purchase Cost:		$	29,666,000.00
Bare Module Cost:		$	55,178,000.00
Associated Costs:	YSZ Support	$	1,206,000.00
Total Bare Module Cost:		$	56,384,000.00
Comments:			

Equipment Cost Summary

The summary of all equipment purchase and bare module costs is presented in the table below. The total cost for plant equipment is $676 MM, 85% of which is attributed to the cost of our reactor complex. This was anticipated to be the largest cost in our process due to the additional capacity needed for regeneration and the requirements of the reformers and oxyreactors. This number is large but in sync with similar projects in industry. A discussion of the reformers and their material needs is discussed in the unit description section and economic analysis section.

HX-101, which exchanges heat between the feed and effluent of the reactor complex, is the most expensive heat exchanger due to its massive area. This large area was required to minimize utilities and maximize energy efficiency.

The C3 separation was also a significant part of the equipment cost due to the high costs of the distillation column and membrane. The high costs of the hybrid approach compared to using just a distillation column are discussed in the other considerations section.

Unit Name	C_p	F_{BM}	Associated Costs	C_{BM}	Quantity	Total C_{BM}
Reactor Complex						
H-101	$ 40,000,000.00	1.86	$0.00	$ 74,400,000.00	1	$ 74,400,000.00
H-102	$ 1,601,000.00	2.56	$0.00	$ 4,098,000.00	1	$ 4,098,000.00
HX-101	$ 210,000.00	6.25	$0.00	$ 1,313,000.00	1	$ 1,313,000.00
R-101 , R-103, R-105, R-107	$ 25,458,000.00	3.81	$7,330,000.00	$ 97,089,000.00	4	$ 417,676,000.00
R-102, R-104, R-106, R-108	$ 154,000.00	4.14	$4,983,000.00	$ 638,000.00	4	$ 22,484,000.00
Subtotal						$ 519,971,000.00
Water Adsorption						
T-201	$ 795,000.00	1.8	$0.00	$ 1,431,000.00	1	$ 1,431,000.00
HX-201	$ 300,000.00	3.21	$0.00	$ 963,000.00	1	$ 963,000.00
AD-201	$ 209,000.00	4.16	$2,042,000.00	$ 869,000.00	2	$ 3,780,000.00
Subtotal						$ 6,174,000.00
CO2 Absorption						
AB-201				$ 3,170,000.00	1	$ 3,170,000.00
Subtotal						$ 3,170,000.00
Distillation Column						
C-201	$ 3,100,000.00	2.3	$0.00	$ 7,130,000.00	1	$ 7,130,000.00
C-202	$ 3,700,000.00	2.3	$0.00	$ 8,510,000.00	1	$ 8,510,000.00
DC-202	$ 1,460,000.00	4.16	$3,933,000.00	$ 6,000,000.00	1	$ 9,933,000.00
Subtotal						$ 25,573,000.00
Hybrid C3 Splitter						
DC-500	$ 13,050,000.00	3.84	$3,066,000.00	$ 50,115,000.00	1	$ 53,181,000.00
P-500	$ 13,300.00	3.31	$0.00	$ 44,000.00	1	$ 44,000.00
HX-500	$ 52,000.00	3.17	$0.00	$ 164,000.00	1	$ 164,000.00
H-500	$ 847,000.00	3.17	$0.00	$ 1,932,000.00	1	$ 1,932,000.00
M-500	$ 29,666,000.00	1.86	$1,206,000.00	$ 55,178,000.00	1	$ 56,384,000.00
C-500	$ 2,442,000.00	2.15	$0.00	$ 5,251,000.00	1	$ 5,251,000.00
H-501	$ 56,000.00	3.17	$0.00	$ 178,000.00	1	$ 178,000.00
H-502	$ 332,000.00	3.17	$0.00	$ 727,000.00	1	$ 727,000.00
C-501	$ 1,424,000.00	2.15	$0.00	$ 3,062,000.00	1	$ 3,062,000.00
Subtotal						$ 120,923,000.00
TOTAL						**$ 675,811,000.00**

Table 4 detailed equipment costs for all units

Fixed-capital Investment Summary

Table 5 summary of fixed costs

Fixed Costs					
Operations					
	Operators per Shift:	1	(assuming	5	shifts)
	Direct Wages and Benefits:	$40	/operator hour		
	Direct Salaries and Benefits:	15%	of Direct Wages and Benefits		
	Operating Supplies and Services:	6%	of Direct Wages and Benefits		
	Technical Assistance to Manufacturing:	$60,000.00	per year, for each Operator per Shift		
	Control Laboratory:	$65,000.00	per year, for each Operator per Shift		
Maintenance					
	Wages and Benefits:	4.50%	of Total Depreciable Capital		
	Salaries and Benefits:	25.00%	of Maintenance Wages and Benefits		
	Materials and Services:	100.00%	of Maintenance Wages and Benefits		
	Maintenance Overhead:	5.00%	of Maintenance Wages and Benefits		
Operating Overhead					
	General Plant Overhead:	7.10%	of Maintenance and Operations Wages and Benefits		
	Mechanical Department Services:	2.40%	of Maintenance and Operations Wages and Benefits		
	Employee Relations Department	5.90%	of Maintenance and Operations Wages and Benefits		
	Business Services	7.40%	of Maintenance and Operations Wages and Benefits		
Property Taxes and Insurance					
	Property Taxes and Insurance:	2.00%	of Total Depreciable Capital		
Straight Line Depreciation					
	Direct Plant:	8.00%	of Total Depreciable Capital, less	1.18	times the Allocated Costs for Utility Plants and Related Facilities
	Allocated Plant:	6.00%	of	1.18	times the Allocated Costs for Utility Plants and Related Facilities
Other Annual Expenses					
	Rental Fees (Office and Laboratory Space):	$0			
	Licensing Fees:	$0			
	Miscellaneous:	$0			
Depletion Allowance					
	Annual Depletion Allowance:	$0			

Operating Cost- Cost of Manufacture

Our variable costs are broken down into raw materials, utility costs, labor costs, and other general expenses that scale with production. The general summary of all costs and investments is shown in the following table.

Table 6 Investment summary

Variable Cost Summary			
Variable Costs at 100% Capacity:			
General Expenses			
Selling / Transfer Expenses:		$	15,278,514
Direct Research:		$	24,445,622
Allocated Research:		$	2,546,419
Administrative Expense:		$	10,185,676
Management Incentive Compensation:		$	6,366,047
Total General Expenses		$	58,822,279
Raw Materials	$0.174126 per lb of Propene		$268,725,912
Byproducts	$0.000000 per lb of Propene		$0
Utilities	$0.050153 per lb of Propene		$77,399,839
Total Variable Costs		**$**	**404,948,029**
Fixed Cost Summary			
Operations			
Direct Wages and Benefits		$	416,000
Direct Salaries and Benefits		$	62,400
Operating Supplies and Services		$	24,960
Technical Assistance to Manufacturing		$	300,000
Control Laboratory		$	325,000
Total Operations		**$**	**1,128,360**
Maintenance			
Wages and Benefits		$	39,756,403
Salaries and Benefits		$	9,939,101
Materials and Services		$	39,756,403
Maintenance Overhead		$	1,987,820
Total Maintenance		**$**	**91,439,726**
Operating Overhead			
General Plant Overhead:		$	3,562,347
Mechanical Department Services:		$	1,204,174
Employee Relations Department:		$	2,960,260
Business Services:		$	3,712,869
Total Operating Overhead		**$**	**11,439,650**
Property Taxes and Insurance			
Property Taxes and Insurance:		$	17,669,512
Other Annual Expenses			
Rental Fees (Office and Laboratory Space):		$	-
Licensing Fees:		$	-
Miscellaneous:		$	-
Total Other Annual Expenses		**$**	**-**
Total Fixed Costs		**$**	**121,677,248**

Investment Summary

Total Bare Module Costs:			
Fabricated Equipment	$	631,391,770	
Process Machinery	$	-	
Spares	$	-	
Storage	$	-	
Other Equipment	$	-	
Catalysts	$	49,252,000	
Computers, Software, Etc.	$	-	
Total Bare Module Costs:			**$ 680,643,770**
Direct Permanent Investment			
Cost of Site Preparations:	$	34,032,189	
Cost of Service Facilities:	$	34,032,189	
Allocated Costs for utility plants and related facilities:	$	-	
Direct Permanent Investment			**$ 748,708,147**
Total Depreciable Capital			
Cost of Contingencies & Contractor Fees	$	134,767,466	
Total Depreciable Capital			**$ 883,475,613**
Total Permanent Investment			
Cost of Land:	$	17,669,512	
Cost of Royalties:	$	-	
Cost of Plant Start-Up:	$	88,347,561	
Total Permanent Investment - Unadjusted			$ 989,492,687
Site Factor			1.00
Total Permanent Investment			**$ 989,492,687**

Working Capital

		2017		2018		2019
Accounts Receivable	$	18,836,524	$	9,418,262	$	9,418,262
Cash Reserves	$	7,363,125	$	3,681,563	$	3,681,563
Accounts Payable	$	(12,801,911)	$	(6,400,956)	$	(6,400,956)
Propene Inventory	$	2,511,537	$	1,255,768	$	1,255,768
Raw Materials	$	662,612	$	331,306	$	331,306
Total	**$**	**16,571,886**	**$**	**8,285,943**	**$**	**8,285,943**
Present Value at 8%	*$*	*15,344,339*	*$*	*7,103,861*	*$*	*6,577,649*

Total Capital Investment		**$ 1,018,518,536**

Other Important Considerations

Plant Location

The proposed plant will be located in Middle East and will produce 700 kilotons of propene a year. This location was chosen to supply the propene needs in the Middle East and Europe (ICIS, 2016). The project will able to avoid the current supply glut of propene in China by focusing on supplying these markets. This location will also minimize propane costs because propane feed stocks are readily available from the oil refinery operations there.

Environmental Problems

Most of the fired heaters throughout the plant burn hydrogen to produce heat which produces hot air and steam. This effluent would need cooling to minimize the local environmental impact. The furnace effluents could be cooled with the incoming boiler water.

Propene emissions are not expected to exceed concentrations in the range of 0.1-4.8 parts per billion (ppb) in rural air and 4-10.5 ppb in urban air. Industrial samples have shown 7-260 ppb which is well below the 500 ppm guideline. It is therefore not considered that propene has any adverse effects on the global environment. Propane is non-toxic and will not create an environmental hazard if released as a liquid or vapor. The only damage potential exists if the vapor is ignited after spill (LFL-2.1% and UFL-10.1%).

Membrane Separation

An important aspect of the design to consider is that the membrane used, ZIF-8, has only ever been implemented on a laboratory scale. This means that all of the data obtained is based on lab results and is assumed to scale to our design parameters. However, this is unlikely to be true due to ideal conditions available in the lab which would be difficult to replicate in a production

plant. For this reason, more research must be done to determine if it is viable to create ZIF-8 membranes on a large enough scale as to be used in our design process for propene-propane separation.

Plant Startup

Special attention should be paid to the plant layout due to the potential hazard of the ignition materials in the process. Startup of the plant though out of scope of the project would increase costs above the predicted values in the profitability analysis provided in Seider, et al. This is due to the amount of heat integration on the process and the size of the recycle streams in the process. The change in the startup cost would however not have a large impact in the profitability of the process as this would ideally require only a singular startup.

Health Information

Propylene storage (liquid) form of propene has the potential to cause frostbite, permanent eye damage, and freeze burn. When handling the storage form of propene appropriate protective garments should be worn to prevent body contact with propene. In vapor form, propene is non-toxic in the recommended 500ppm and is toxic at high concentration (300,000ppm). Propene is not likely to cause cancer even when inhaled. Similar considerations should be made for propane as propylene when handling the liquid form of propane. The vapor form however may cause headaches, dizziness and myocardial irritability after excessive exposure.

Physical Hazard Information

Propylene is a flammable liquid and vapor with high vapor pressure. The lower flammability level for propylene is about 20,000 ppm, and the flash point is -162ºF (- 108ºC). Liquid propylene may release flammable vapors below ambient temperature and forms a flammable mixture with air. Propylene vapor are heavier than air, and may travel long distance

to an ignition point or flash back. Therefore, propylene should be handled only with adequate ventilation and in areas where ignition sources have been removed. Propylene can only be stored in approved container such as bond and ground container to keep propylene away from flame, spark and excessive temperature. Empty product container or vessel should be returned to the Supplier or contact AmeriGas for safe disposal. If flammability levels are reached, evacuate the area and call emergency response personnel.

As a flammable liquefied gas under pressure, propane should be kept away from heat, spark, flame and all other ignition sources. Propane should store in a safe, authorized location with adequate since propane is heavier than air, and can collect in low areas that are without sufficient ventilation. If there is spill of the material, do not attempt to extinguish fire until propane source is isolated. Dry chemical, CO2, water and fog can be used as extinguishing media to put out fire. Propane, propylene and hydrogen concentrations are maintained above their UEL by feeding small oxygen concentrations to the reactors.

Profitability Analysis – Business Case

The economic analysis of this project is summarized in the following tables. Based on standard practice in the commodity chemicals industry, a conservative plant life of 20 years was chosen. At current prices of propene and propane, the process using the STAR technology and a hybrid membrane is not economical.

While the hybrid system for propene separation was fully developed in our analysis due to its previously stated optimization in terms of cost, the options of using only a distillation column and using only a membrane were also explored. The bare module cost of the hybrid system was found to be $120 million with a utility cost of $16.2 million. Using only a distillation column, the bare module cost increases to $182.5 million while the total utility cost per year decreases to $12.7 million. The membrane only separation system has the highest utility cost of $8 million per year and the highest bare module cost of $275 million. It should be noted that membrane costs may be off by as much as a factor of ten due to material costs being based on purchasing low quantity amounts whereas the membrane design calls for a large quantity of materials to be bought and used. This results in a very ambiguous set of values related to the bare module cost of the membrane and hybrid systems. Without having more accurate purchase price date for the materials used in making the membrane, it is difficult to draw a reasonable conclusion as to which method of separation is most cost effective and efficient.

Table 7 Profitability analysis

General Information

Process Title:	**Propane Dehydrogenation By Autothermal Reforming**
Product:	**Propene**
Plant Site Location:	**Middle East**
Site Factor:	**1.00**
Operating Hours per Year:	**7919**
Operating Days Per Year:	**330**
Operating Factor:	**0.9040**

Product Information

This Process will Yield

	194,883	lb of Propene per hour
	4,677,186	lb of Propene per day
	1,543,284,240	lb of Propene per year
Price	**$0.33**	**/lb**

Chronology

Year	Action	Distribution of Permanent Investment	Production Capacity	Depreciation 5 year MACRS	Product Price
2016	Design		0.0%		
2017	Construction	100%	0.0%		
2018	Production	0%	45.0%	20.00%	$0.33
2019	Production	0%	67.5%	32.00%	$0.33
2020	Production	0%	90.0%	19.20%	$0.33
2021	Production		90.0%	11.52%	$0.33
2022	Production		90.0%	11.52%	$0.33
2023	Production		90.0%	5.76%	$0.33
2024	Production		90.0%		$0.33
2025	Production		90.0%		$0.33
2026	Production		90.0%		$0.33
2027	Production		90.0%		$0.33
2028	Production		90.0%		$0.33
2029	Production		90.0%		$0.33
2030	Production		90.0%		$0.33
2031	Production		90.0%		$0.33
2032	Production		90.0%		$0.33

Equipment Costs

Equipment Description		Bare Module Cost
H-101	Fabricated Equipment	$74,400,000
H-102	Fabricated Equipment	$4,098,000
HX-101	Fabricated Equipment	$1,313,000
R-101	Fabricated Equipment	$97,089,000
R-102	Fabricated Equipment	$638,000
R-103	Fabricated Equipment	$97,089,000
R-104	Fabricated Equipment	$638,000
R-105	Fabricated Equipment	$97,089,000
R-106	Fabricated Equipment	$638,000
R-107	Fabricated Equipment	$97,089,000
R-108	Fabricated Equipment	$638,000
T-201	Fabricated Equipment	$1,431,000
HX-201	Fabricated Equipment	$963,000
AD-201	Fabricated Equipment	$2,911,770
AB-201	Fabricated Equipment	$3,870,000
C-201	Fabricated Equipment	$7,130,000
C-202	Fabricated Equipment	$8,510,000
DC-202	Fabricated Equipment	$9,933,000
DC-500	Fabricated Equipment	$59,911,000
P-500	Fabricated Equipment	$44,000
HX-500	Fabricated Equipment	$164,000
H-500	Fabricated Equipment	$203,000
M-500	Fabricated Equipment	$56,384,000
C-500	Fabricated Equipment	$5,251,000
H-501	Fabricated Equipment	$178,000
H-502	Fabricated Equipment	$727,000
C-501	Fabricated Equipment	$3,062,000
.2-.6% Pt-Sn/ZnAl2O6	Catalysts	$49,252,000

Raw Materials

	Raw Material:	Unit:	Required Ratio:		Cost of Raw Material:	
1	Propane	lb	1.2222	lb per lb of Propene	$0.134	per lb
2	Oxygen	lb	0.1362	lb per lb of Propene	$0.08	per lb
	Total Weighted Average:				$0.174	per lb of Propene

Byproducts

	Byproduct:	Unit:	Ratio to Product	Byproduct Selling Price
	Total Weighted Average:			$0.000E+00 per lb of Propene

Utilities

	Utility:	Unit:	Required Ratio		Utility Cost	
1	MEA Capture System	unit	6.48E-10	unit per lb of Propene	$1330000.000	per unit
2	Nitrogen	CF	0.00276	CF per lb of Propene	$0.078	per CF
3	Chilled Water	GJ	0.00017	GJ per lb of Propene	$5.000	per GJ
4	Cooling Water	gal	26.72	gal per lb of Propene	$1.000E-04	per gal
5	Electricity	kWh	0.1453	kWh per lb of Propene	$0.070	per kWh
6	Natural Gas	MMBTU	0.00117	MMBTU per lb of Propene	$1.780	per MMBTU
7	Refrigeration (-150°F)	GJ	0.001	GJ per lb of Propene	$33.30	per GJ
	Total Weighted Average:				$0.050	per lb of Propene

Variable Costs

General Expenses:

Selling / Transfer Expenses:	3.00% of Sales
Direct Research:	4.80% of Sales
Allocated Research:	0.50% of Sales
Administrative Expense:	2.00% of Sales
Management Incentive Compensation:	1.25% of Sales

Working Capital

Accounts Receivable	⇨	30	Days
Cash Reserves (excluding Raw Materials)	⇨	30	Days
Accounts Payable	⇨	30	Days
Propene Inventory	⇨	4	Days
Raw Materials	⇨	2	Days

Total Permanent Investment

Cost of Site Preparations:	5.00% of Total Bare Module Costs
Cost of Service Facilities:	5.00% of Total Bare Module Costs
Allocated Costs for utility plants and related facilities:	$0
Cost of Contingencies and Contractor Fees:	18.00% of Direct Permanent Investment
Cost of Land:	2.00% of Total Depreciable Capital
Cost of Royalties:	$0
Cost of Plant Start-Up:	10.00% of Total Depreciable Capital

Fixed Costs

Operations

Operators per Shift:	1 (assuming 5 shifts)
Direct Wages and Benefits:	$40 /operator hour
Direct Salaries and Benefits:	15% of Direct Wages and Benefits
Operating Supplies and Services:	6% of Direct Wages and Benefits
Technical Assistance to Manufacturing:	$60,000.00 per year, for each Operator per Shift
Control Laboratory:	$65,000.00 per year, for each Operator per Shift

Maintenance

Wages and Benefits:	4.50% of Total Depreciable Capital
Salaries and Benefits:	25% of Maintenance Wages and Benefits
Materials and Services:	100% of Maintenance Wages and Benefits
Maintenance Overhead:	5% of Maintenance Wages and Benefits

Operating Overhead

General Plant Overhead:	7.10% of Maintenance and Operations Wages and Benefits
Mechanical Department Services:	2.40% of Maintenance and Operations Wages and Benefits
Employee Relations Department:	5.90% of Maintenance and Operations Wages and Benefits
Business Services:	7.40% of Maintenance and Operations Wages and Benefits

Property Taxes and Insurance

Property Taxes and Insurance:	2% of Total Depreciable Capital

Straight Line Depreciation

Direct Plant:	8.00% of Total Depreciable Capital, less 1.18 times the Allocated Costs for Utility Plants and Related Facilities
Allocated Plant:	6.00% of 1.18 times the Allocated Costs for Utility Plants and Related Facilities

Other Annual Expenses

Rental Fees (Office and Laboratory Space):	$0
Licensing Fees:	$0
Miscellaneous:	$0

Depletion Allowance

Annual Depletion Allowance:	$0

Cash Flow Summary

Year	Percentage of Design Capacity	Product Unit Price	Sales	Capital Costs	Working Capital	Var Costs	Fixed Costs	Depreciation	Depletion Allowance	Taxible Income	Taxes	Net Earnings	Cash Flow	Cumulative Net Present Value at 8%
2016	0%		-	-	-	-	-	-	-	-	-	-	-	-
2017	0%		-	(989,492,700)	(16,571,900)	-	-	-	-	-	-	-	(1,006,064,600)	(931,541,300)
2018	45%	$0.33	229,177,700	-	(8,285,900)	(182,226,600)	(121,677,200)	(176,695,100)	-	(251,421,300)	93,025,900	(158,395,400)	10,013,800	(922,956,100)
2019	68%	$0.33	343,766,600	-	(8,285,900)	(273,339,900)	(121,677,200)	(282,712,200)	-	(333,962,800)	123,566,200	(210,396,600)	64,029,700	(872,127,200)
2020	90%	$0.33	458,355,400	-	-	(364,453,200)	(121,677,200)	(169,627,300)	-	(197,402,400)	73,038,900	(124,363,500)	45,263,800	(838,857,000)
2021	90%	$0.33	458,355,400	-	-	(364,453,200)	(121,677,200)	(101,776,400)	-	(129,551,400)	47,934,000	(81,617,400)	20,159,000	(825,137,100)
2022	90%	$0.33	458,355,400	-	-	(364,453,200)	(121,677,200)	(101,776,400)	-	(129,551,400)	47,934,000	(81,617,400)	20,159,000	(812,433,500)
2023	90%	$0.33	458,355,400	-	-	(364,453,200)	(121,677,200)	(50,888,200)	-	(78,663,300)	29,105,400	(49,557,800)	1,330,300	(811,657,300)
2024	90%	$0.33	458,355,400	-	-	(364,453,200)	(121,677,200)	-	-	(27,775,100)	10,276,800	(17,498,300)	(17,498,300)	(821,111,100)
2025	90%	$0.33	458,355,400	-	-	(364,453,200)	(121,677,200)	-	-	(27,775,100)	10,276,800	(17,498,300)	(17,498,300)	(829,864,600)
2026	90%	$0.33	458,355,400	-	-	(364,453,200)	(121,677,200)	-	-	(27,775,100)	10,276,800	(17,498,300)	(17,498,300)	(837,969,700)
2027	90%	$0.33	458,355,400	-	-	(364,453,200)	(121,677,200)	-	-	(27,775,100)	10,276,800	(17,498,300)	(17,498,300)	(845,474,400)
2028	90%	$0.33	458,355,400	-	-	(364,453,200)	(121,677,200)	-	-	(27,775,100)	10,276,800	(17,498,300)	(17,498,300)	(852,423,200)
2029	90%	$0.33	458,355,400	-	-	(364,453,200)	(121,677,200)	-	-	(27,775,100)	10,276,800	(17,498,300)	(17,498,300)	(858,857,300)
2030	90%	$0.33	458,355,400	-	-	(364,453,200)	(121,677,200)	-	-	(27,775,100)	10,276,800	(17,498,300)	(17,498,300)	(864,814,800)
2031	90%	$0.33	458,355,400	-	-	(364,453,200)	(121,677,200)	-	-	(27,775,100)	10,276,800	(17,498,300)	(17,498,300)	(870,330,900)
2032	90%	$0.33	458,355,400	-	33,143,800	(364,453,200)	(121,677,200)	-	-	(27,775,100)	10,276,800	(17,498,300)	15,645,500	(865,764,200)

Profitability Measures	
The Internal Rate of Return (IRR) for this project is	Negative IRR
The Net Present Value (NPV) of this project in 2016 is	$ (865,764,200)

ROI Analysis (Third Production Year)

Annual Sales	458,355,419
Annual Costs	(486,130,474)
Depreciation	(79,159,415)
Income Tax	39,565,754
Net Earnings	(67,368,716)
Total Capital Investment	1,022,636,460
ROI	-6.59%

Table 7 contains the results of the profitability analysis of this project at current market conditions. For capital investment accounting purposes, a five year MACRS depreciation schedule was chosen. The profitability analysis was conducted assuming one year of construction time and three years to ramp up to full production. Equipment costs were reported using estimates from Seider, et. al, 2009. The estimates for variable cost include the raw materials, utilities, and general expenses necessary for production. The fixed cost estimates include operations, maintenance, operating overhead, taxes, and depreciation. Although the best effort was made to minimize variable and fixed costs, we acknowledge that there is always room for improvement in the plant design and these costs may be able to be reduced further.

This project is highly sensitive to crude prices and the margin between propane and propene. The IRR of this project as a function of the price of propene in shown below in Figure 8.

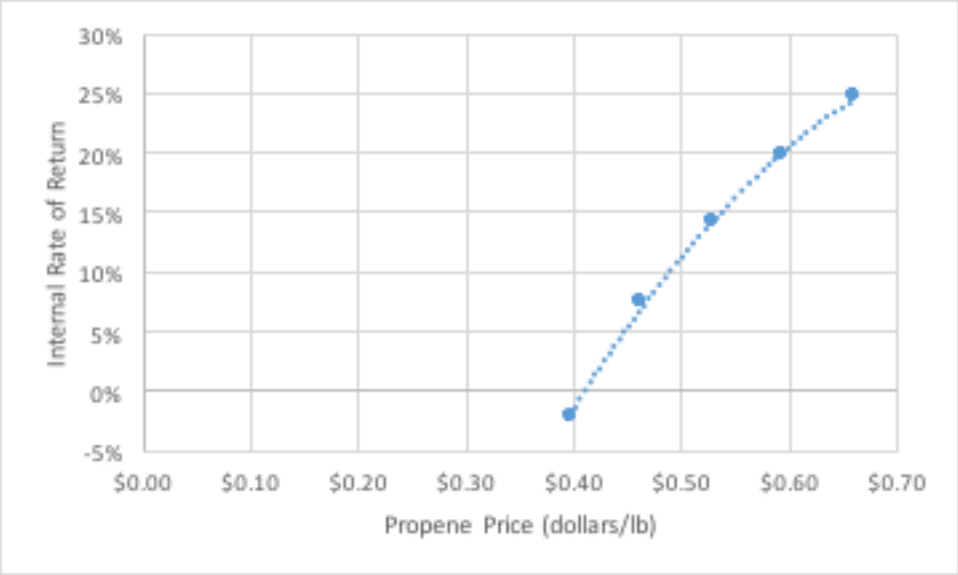

Figure 8- IRR as a function of price of propene

Sensitivity analysis were also conducted to analyze the effect of changes in total permanent investment, variable costs, and fixed costs on overall profitability. These results are presented in Table 8 below. Using these analyses, it is possible to determine that even if the alternative methods of C3 separation were used, the project is not financially feasible under current economic conditions.

At current market prices, this design is not expected to be profitable due to a negative IRR and an NPV of $857,000,000. However, economic feasibility depends on volatile market conditions. Market research shows that propene prices will remain depressed over the next few years due to increased on-purpose production coming online and softer demand. In positive news, however, the price of propane is also expected to remain depressed. As the following table shows, the price of propene has to rise above $0.43 for this process to make economic sense. Fortunately, the price of propane is not highly correlated with the price of propene, making the possibility of this price gap rise possible. As recent as 2015, prices of propene hovered around $0.50 which would allow for an IRR of 11% at our current variable costs. Market analysis has

shown that other companies have already taken advantage of this opportunity in the past few years, shifting the market dramatically. This project may make sense in the long term as reduced production of propene from steam cracker and refineries will drive up prices.

Table 8: Expected IRR as function of Fixed Costs, Variable Costs, and Total Permanent Investment

Fixed Costs

Product Price	$60,838,624	$73,006,349	$85,174,074	$97,341,799	$109,509,523	***$121,677,248***	$133,844,973	$146,012,698	$158,180,423	$170,348,147	$182,515,872
.00%	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR
6.60%	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR
$0.13	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR
$0.20	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR
$0.26	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR
$0.33	-6.84%	-9.61%	-13.20%	-18.55%	-29.88%	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR
$0.40	5.16%	3.88%	2.53%	1.10%	-0.43%	-2.09%	-3.92%	-5.99%	-8.38%	-11.29%	-15.12%
$0.46	12.60%	11.61%	10.61%	9.58%	8.52%	7.43%	6.30%	5.13%	3.90%	2.62%	1.27%
$0.53	18.55%	17.69%	16.83%	15.95%	15.06%	14.16%	13.24%	12.31%	11.35%	10.38%	9.38%
$0.59	23.73%	22.95%	22.16%	21.36%	20.56%	19.75%	18.93%	18.11%	17.27%	16.43%	15.58%
$0.66	28.44%	27.70%	26.95%	26.20%	25.45%	24.70%	23.94%	23.18%	22.41%	21.64%	20.86%

Variable Costs

Product Price	$202,474,015	$242,968,817	$283,463,620	$323,958,423	$364,453,226	***$404,948,029***	$445,442,832	$485,937,635	$526,432,438	$566,927,241	$607,422,044
.00%	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR
6.60%	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR
$0.13	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR
$0.20	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR
$0.26	-2.32%	-8.86%	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR
$0.33	7.49%	4.14%	0.16%	-5.00%	-13.42%	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR
$0.40	14.31%	11.75%	8.96%	5.86%	2.28%	-2.09%	-8.16%	-20.61%	Negative IRR	Negative IRR	Negative IRR
$0.46	19.96%	17.76%	15.44%	12.98%	10.34%	7.43%	4.15%	0.29%	-4.63%	-12.13%	Negative IRR
$0.53	24.96%	22.97%	20.91%	18.77%	16.53%	14.16%	11.63%	8.88%	5.83%	2.34%	-1.88%
$0.59	29.53%	27.69%	25.79%	23.85%	21.83%	19.75%	17.57%	15.28%	12.85%	10.23%	7.37%
$0.66	33.81%	32.07%	30.29%	28.47%	26.61%	24.70%	22.73%	20.69%	18.57%	16.35%	14.01%

Total Permanent Investment

Product Price	$494,746,344	$593,695,612	$692,644,881	$791,594,150	$890,543,418	***$989,492,687***	$1,088,441,956	$1,187,391,224	$1,286,340,493	$1,385,289,762	$1,484,239,031
.00%	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR
6.60%	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR
$0.13	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR
$0.20	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR
$0.26	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR
$0.33	8.14%	-0.46%	-8.12%	-16.56%	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR	Negative IRR
$0.40	30.02%	19.77%	12.37%	6.64%	1.94%	-2.09%	-5.71%	-9.08%	-12.37%	-15.74%	-19.45%
$0.46	45.61%	32.68%	23.66%	16.95%	11.70%	7.43%	3.83%	0.71%	-2.06%	-4.57%	-6.88%
$0.53	59.05%	43.51%	32.80%	24.96%	18.95%	14.16%	10.21%	6.87%	3.98%	1.44%	-0.84%
$0.59	71.25%	53.25%	40.89%	31.92%	25.11%	19.75%	15.39%	11.75%	8.64%	5.94%	3.55%
$0.66	82.59%	62.26%	48.32%	38.25%	30.64%	24.70%	19.91%	15.94%	12.58%	9.69%	7.16%

Conclusion

The design and profitability analysis for the process to manufacture 700 kT/year of polymer grade propene from propane oxydehydrogenation has been presented. The reduction in propene supplies from steam cracker and refineries, in combination with the resulting higher price levels, are supporting investment in on-purpose production. However, market analysis has shown that other companies have already taken advantage of this opportunity in the past 3 years, shifting the market dramatically. Under current economic conditions, the project has an estimated NPV of -$865MM and a negative IRR. This project may make economic sense if a rebound in the price of propene is expected in the future.

The largest factor affecting the degree of profitability for this project is the margin between propane and propene. Due to the recent large investments in PDH plants by companies around the world, the market is unattractive to producers in the short term. Currently, plants are producing at 70% capacity to avoid flooding the market with propene. However, potential increases in the price of propene may make this design economical, especially considering a plant life of 20 years.

In addition to improving the propane/propene price margin, another way to improve the feasibility of this project is to decrease capital and operating costs. The capital costs are very large for this project due to the high temperatures at which the reactors are run and the need for excess capacity for regeneration. While there is room for improvement, this design is still within a factor of 2 of the cost of similar plants built in the Philadelphia area. Discussions with industry sources have also indicated that the UOP process is more economical that the STAR by Thyssen Krupp process that this design uses.

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Appendix A: Sample Calculations

Reactor Calculations

$m_{catalyst} = catalyst\ loading\ weight\ (lb)$
$m_{propane} = propane\ feed\ flowrate\ \left(\frac{lb}{hr}\right)$
$WHSV = weighted\ hourly\ space\ velocity\ (hr^{-1})$
$V_R = reactor\ volume\ (ft^3)$
$\rho_{bulk} = bulk\ density\ of\ packed\ bed\ \left(\frac{lb}{ft^3}\right)$
$\rho_{particle} = density\ of\ catalyst\ particle\ \left(\frac{lb}{ft^3}\right)$
$\epsilon = void\ fraction$
$\tau = residence\ time\ (hr)$
$Q = Volumetric\ flowrate\ \left(\frac{ft^3}{hr}\right)$
$D_i = inner\ tube\ diameter\ (ft)$
$k = thermal\ conductivity\ of\ packed\ bed\ \left(\frac{Btu}{hr\ *^o F * ft}\right)$
$h = convective\ heat\ transfer\ of\ air\ \left(\frac{Btu}{hr\ *^o F * ft^2}\right)$
$Bi = Biot\ number, Bi < 0.1\ for\ zero\ temperature\ gradient$
$L = tube\ length\ (ft)$
$N = number\ of\ tubes$
$t_{sp} = wall\ thickness\ (ft)$
$P_d = design\ pressure\ (psia)$
$S = maximum\ allowable\ stress\ of\ shell\ material\ (psia)$
$E = fractional\ weld\ efficiency$
$\rho_m = material\ density\ \left(\frac{lb}{ft^3}\right)$
$W = vessel\ weight\ (lb)$
$v_s = superficial\ velocity\ \left(\frac{ft}{s}\right)$
$D_p = particle\ diameter\ (in)$
$\phi = thiele\ modulus$
$r = reaction\ rate\ \left(\frac{psia}{s}\right)$
$D_c = diffusion\ rate\ \left(\frac{psia}{s}\right)$
$\Delta p = pressure\ drop\ \left(\frac{psia}{s}\right)$
$\mu = dynamic\ viscosity\ of\ fluid\ \left(\frac{lb}{ft * hr}\right)$

$$\rho_f = density\ of\ fluid\ (\frac{lb}{ft^3})$$

$$m_{catalyst} = \frac{m_{propane}}{WHSV}$$

$$V_R = \frac{m_{catalyst}}{\rho_{bulk}}$$

$$\tau = \frac{V_R}{Q}$$

$$\epsilon = 1 - \frac{\rho_{bulk}}{\rho_{particle}}$$

$$D_i = \frac{kBi}{h}$$

$$N = \frac{V_R}{D_i^2 L}$$

$$t_{sp} = \frac{P_d D_i}{2SE - 1.2P_d}$$

$$W = \pi\left(D_i + t_{sp}\right)(L + 0.8D_i)t_{sp}\rho_m$$

$$v_s = \frac{Q}{\frac{\pi}{4}D_i^2}$$

$$\phi = \frac{r}{D_c}$$

$$\Delta p = \frac{150\mu L}{D_p^2}\frac{(1-\epsilon)^2}{\epsilon^3}\ v_s + \frac{1.75L\rho_f}{D_p}\frac{(1-\epsilon)}{\epsilon^3}v_s|v_s|$$

Adsorption Column Calculations Procedure and Considerations

1.Determine the content of the component(s) that are to be removed from the process stream in question. If a reactor with solid/bed catalyst obviously this is not pertinent.

2.Find a suitable adsorbent and the likely "loading" that is applicable. That is how many pounds of the component per 100 pounds of adsorbent are applicable. This is from supplier's data or literature data to be confirmed by a supplier.

3.Typical “CYCLE TIMES” for a system in which the component content is essentially constant or near constant are 8, 12 or 24 hours. That is the CYLCLE represents the total time period from the moment the bed goes “on stream” to the time it has been regenerated and is ready to “go on stream” again.

The selection of the cycle times is such that it may more likely end and start with a “shift change” of operators. Now the 12-hour cycle would not meet that criterion but would mean that it is to be completed every day at the same time by whatever crew is on shift!

4.In the case where the process stream impurities are not known and/or are not constant; or are at a very low concentration and the cycle might be for a month or more. Example: oftentimes a product stream contains a detectable impurity and it must be removed, but its actual chemical structure is not known, the application of activated carbon is used to remove it. The applicability of the activated carbon would have been determined by experimental work. In this case it is often the norm to include only one such bed and the contents (activated carbon) are replaced rather than regenerated.

5.Having determined the amount to be removed per hour and the loading and selecting a cycle time we can size the bed; i.e., calculate the pounds/volume of adsorbent required.

6.An L/D of 3/1 is a good rule of thumb for the dimensions of the bed holding vessel. Allow for the volume of the “heads” of the vessel to be filled with “ceramic balls” to assist in distribution of the process gas both at the inlet and the outlet. So, only the “straight height” of the vessel will be filled with absorbent.

7.Remember that the higher the pressure the greater the wall thickness of the vessel will be. This criterion may influence your L/D choice as the smaller the diameter the smaller the wall thickness (and the price of the vessel in general).

8.As a rule two beds are placed in service. One is on stream while the other is regenerated and made ready to go on stream. A sketch will be sent separately from this note.

9.Normally the “heat of adsorption” is not sufficient to raise the bed temperature significantly. However, it should be looked at to be certain. The heat of adsorption is not normally available and one can use the heat of condensation (latent heat) as an approximation. If there is a significant heating effect one should consider cooling the inlet gas to account for the heating of the bed to attempt to hold it isothermal.

10.Next one must calculate the “total heat content” of the bed; vessel and associated piping and valves to determine how much heat must be added to the bed and associated equipment to reach the “required regeneration temperature”. For driers and carbon/molecular sieve adsorbers a temperature of 300 degrees F is sufficient. Driers and molecular sieve adsorbers can be operated at 100 degrees F and oftentimes they are operated at 40 degrees F to increase their adsorptive capacity significantly. The trade-off between the smaller bed and associated equipment is the higher cost of the refrigeration load to cool the bed back down to 40 degrees F.

Remember the heat content of the vessel and piping and valves must be included. The vessels will be insulated to reduce heat losses and the insulation content can be ignored.

11.For a rough estimate at the early stage of a design at which time the piping and valves have not been selected/designed lets simply use a factor of 1.25 times the bed and vessel heat content as the total heat load.

12.Now let's look at the process sketch while a description of the events take place:
· The newly regenerated bed will be brought on stream by "cracking open" the inlet valve to pressurize the bed.
· When the operating pressure is reached the outlet valve will be opened slowly such that the process stream is now distributing between the "old bed" and the "new bed".
· Next the outlet valve of the old bed is slowly closed until all the flow is passing through the new bed.
· The inlet to the old bed is closed.
· Now the old and new beds are isolated from each other and the regeneration process can take place.
· The old bed will be at the operating pressure and must be relieved to near atmospheric pressure.
· The disposal or recovery of the relieving gases is to be considered in your design. It cannot as a rule be relieved to the atmosphere and if it is toxic it must receive special consideration.

13. Next the regeneration begins:
· There is an external recirculation loop that contains a recirculation blower, a heater, a cooler if the component to be removed is water or a material that can be readily condensed and sent to treatment, a "knock-out pot" (simply a vessel to separate vapor from liquid), pressure control systems (two) to relieve the system as the system heats up and the gases in the "closed loop" expand and would raise the loop pressure if not relieved and the other to allow an inert gas to enter the loop during the cooling cycle to prevent the loop pressure from falling due to a contraction of the gases as the system cools.
· Steam, hot oil or an electric heater can supply the heat to the recirculation system if the high temperature is not available via the other media. The inlet temperature to the bed will be 350 degrees F as a rule but must be verified with the supplier and for the specific application.
· The gas used in the loop can be one of several choices and depending on the bed composition and the material that is being desorbed. The gas could be whatever gas is the process gas; nitrogen (provided as make-up only and not once through) and some cases could be air if the oxygen content would not cause a deterioration or safety hazard.
· The bed is at T operating, say 100 Degrees F. and the hot gas enters at 350 Degrees F. As a simplifying assumption and by the way this works out quite reasonably one will assume that the hot gas is cooled to the bed temperature, 100 Degrees F in this case, as it exits the bed; this will be the case for one half of the heat up period. By the way the total regeneration cycle is 8 or 12 hours most likely and one must allow 1 hour for switching valves, depressurization and other tasks for the transition. So as a for instance assume that the cycle is 8 hours then there is 7 hours for the heating and cooling of the bed and the one hour for switching, depressurization and repressurization.
· For the second half of the heating period (as of yet not specified beyond 7 hours for heating and cooling) one assumes that the temperature out of the bed is a "straight line" between 100 Degrees F and 300 Degrees F. Or that on average during the second half of the heating period the hot gas exits the bed at the average temperature or 200 Degrees F. Remember for a solid bed the temperature profile will be quite flat until the bed heats up along its length and along the way the

exit temperature will begin to rise. Detailed dynamic calculations would show that the shape of the exit case temperature curve with time would be exponential in shape. Perhaps the upswing half of a parabola would describe it better.
· Given these pieces of information; the heat load, the temperature profile of the exit heated gas and the heat capacity of the regeneration (heated gas) the "total flow" of the regeneration (heated gas) can be calculated. This does not answer how long the heating period will be; that will be computed later!
· Next we compute the cooling load required to bring the bed and associated equipment back to operating temperature, in this example 100 Degrees F.
· Now the flow in the regeneration loop is valved so that the blower output goes through the cooler and not the heater so that gas the supply to the bed is 100 Degrees F. In general, the flow to the beds is in the downward direction so that the bed will not be subjected to a "lift" during normal flow and regeneration.
· During cooling the same criteria are applied to the temperatures leaving the bed; during the first half of the cooling cycle the temperature of the exit gas is the same as the bed (350 degrees F); during the second half the temperature is the average of 350 and 100 degrees F or 225 degrees F. From the cooling load, the gas heat capacity and the delta T's the amount of gas required can be calculated.
· Now the total amount of regeneration gas required for both the heating and the cooling periods is known by the simple summation of the two. Remember that in this case the total time for regeneration is 8 – 1 = 7 hours. Therefore, the gas flow rate will be the total gas calculated divided by 7 hours. For blower design this should be converted to actual cubic feet per minute.
· Now the actual duration of the heating and cooling periods is simply the ratio between the total gas required and the fraction of gas for cooling or heating which must add up to 1 times the 7 hours.

14.OTHER CONCERNS:
· The blower will heat up the recirculation gas and will then contribute to the heating requirements. Don't ignore this.
· The cooler is used in the suction of the blower to condense out water if present. Otherwise if the regeneration gas is removing carbon dioxide or some other gas that does not condense then the cooler is not needed if the blower capacity can be such that the hot gas return can be directly added to the blower suction. Remember that the blower capacity is greatly reduced if the inlet temperature (and hence the volume is increased lowering the capacity of the blower) is increased.
· When removing "other" gases and not water, the recycle loop gases need to be purged at "some rate" to be certain that the adsorbed component is desorbed. Judgment is required here.

Catalyst Burn Regeneration Calculations

Objective

1) Describe a method for removal of hydrocarbon or carbon residue that deposits on catalyst during normal operation

2) This is done via controlled temperature and oxygen content of "burn-off" vapor circulation.

Issues of concern:

1) Maximum temperature allowed for catalyst during regeneration
2) Maximum amount of hydrocarbon(carbon) build up allowed between regenerations
3) Lower explosive limit (lel) for oxygen in "burn gas" if applicable
4) What is the maximum temperature of the bed/contents be allowed?
5) What temperature of the "burn gas" will be selected for the "burn"?
6) What temperature will the bed/contents be cooled to before placing
7) What composition of the recirculation gas?

Calculations:

1) Research the lel for oxygen in burn gas mixture if applicable and select a level of 50 % of lel or less. This will be moderated by the maximum temperature in bed allowed.
2) The burn cycle will start by purging the vessels and piping with nitrogen to avoid explosive mixtures
3) Start burn with appropriate oxygen % and use cooled combustion gas as carrier gas.
4) Select the burn gas inlet temperature based on maximum desired temperature in the bed.
5) Calculate the the exit temperature of the burn gas as: for one half the time the exit gas of the reactor will be approximated as the cold end of the reactor assuming that for an endothermic reaction this is significantly colder than the inlet end of the bed.
6) If the entire bed is at the same temperature use it.
7) For the second half of the burn cycle use the burn temperature as the outlet of the recirculating gas.
8) Use the average of these two temperature values as the approximate for the average temperature of the recirculation gas for the burn gas.
9) The exit combustion/recirculation gas must be cooled to the desired colder temperature and recirculated to the reactor
10) Calculate the q value to cool the weight of the vessel (multiply that by 1.5 to include the piping and valves); the catalyst bed; and the insulation. Then calculate the q to be removed from the operating temperature to say 300 f in this case.
11) Now you can decide how long the burn cycle will take to burn all of the carbon off the catalyst. You have decided how long you will operate the reactor and the carbon build

up. Given the lbs of carbon you can calculate the amount of oxygen that you need at the "safe" oxygen

12) Concentration to burn it off. Pick the time for burn and then you can simply calculate the flow rate of burn gas required to remove all of the carbon.

13) Using the weights calculating above of the vessel and etc. Calculate the q to be removed for the cool-down. Using the average temperatures for cooling described above, pick a time and with the q and time desired you can calculate the flowrate for cooling required.

Remember now that during the burn cycle and the cooling cycle there is a need to cool the recirculation gas before it returns to the reactor. Also, there is a need to purge or add to the recirculation gas during burn and cooling.

Membrane Calculations

$$\text{PermA} = \frac{\text{F}_p * Y_a}{\text{A} * \Delta P_a}$$

$$\Delta P_a = \frac{P_f * Z_a - X_a * P_r}{\ln \frac{P_f * Z_a}{X_a * P_r}}$$

$$F_p = \frac{\text{PermA}}{Y_a} * \frac{P_f * Z_a - P_r * X_a}{\ln \frac{P_f * Z_a}{P_r * X_a}} - Y_a * P_p$$

$$F_p = \frac{\text{PermA}}{1 - Y_a} * \frac{P_f * (1 - Z_a) - P_r * (1 - X_a)}{\ln \frac{P_f * (1 - Z_a)}{P_r * (1 - X_a)}} - (1 - Y_a) * P_p$$

$$F_r = \frac{(Z_a - Y_a) * F_f}{X_a - Y_a}$$

$$\text{Area} = \frac{Y_a * F_p}{\left(\frac{P_f * Z_a - X_a * P_r}{\ln \frac{P_f * Z_a}{X_a * P_r}} - Y_a * P_p \right) * \text{PermA}}$$

F_f = Feed Flow
F_p = Permeate flow
F_r = Retentate flow

Y_a = Permeate Propylene comp
X_a = Retentate Propylene comp
Z_a = Feed Propylene comp
P_p = Permeate pressure
P_r = Retentate Pressure
P_f = Feed Pressure
S = Selectivity
PermA = Permeability propylene
PermB = Permeability propane

Pump Calculations

$W = 7.27x10^{-5} * F * \Delta P$
W = work (HP)
F = volumetric flowrate (ft^3/hr)
ΔP = pressure change (psia)

$$H = \frac{\Delta P}{\rho_L}$$

H = head (ft)
ρ_L = liquid's density (lb/ft^3)

Heat Exchanger Calculations

$$Q = UA\Delta T_{LM} = \frac{((T_{hi} - T_{co}) - (T_{ho} - T_{ci}))}{\ln \frac{(T_{hi} - T_{co})}{(T_{ho} - T_{ci})}}$$

Q= duty of the exchanger (BTU/hr)
U= heat exchanger transfer coefficient (BTU/hr/ft/F)
A= Surface area of the exchanger (ft^2)
T_{hi} = inlet temperature of hot stream (R)
T_{ho} = outlet temperature of hot stream (R)
T_{ci} = inlet temperature of cold stream (R)
T_{co} = outlet temperature of cold stream (R)

Reflux Accumulator Calculations

F= (1+R) ($D_{volumetric}$)
Volume = 2*F*τ
Assume L/D=2

$$D = \left(\frac{2V}{\pi}\right)^{\frac{1}{3}}$$

F = volumetric flow rate (ft^3/hr)
$D_{volumetric}$ = distillate flow rate (ft^3/hr)
R = reflux ratio
L = length of drum (ft)
D = diameter of drum (ft)
τ = residence time (hr)

Distillation Column Calculations

$$U_f = C_{SB} F_{ST} F_F F_{HA} \left(\frac{\rho_L - \rho_V}{\rho_V}\right)^{\frac{1}{2}}$$

$$F_{ST} = \left(\frac{\sigma}{20}\right)^{\frac{1}{5}}$$

$$F_{LG} = \frac{L}{V}\left(\frac{\rho_V}{\rho_V}\right)^{\frac{1}{2}}$$

$$U = .85 * U_f$$

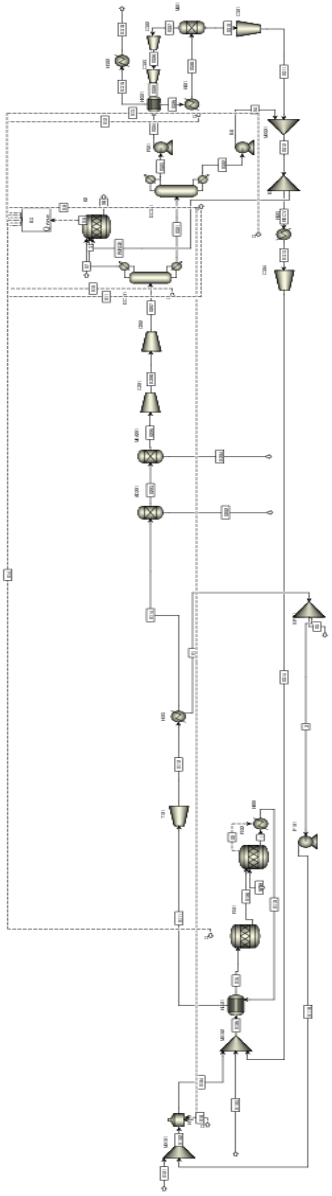
$$\mathrm{D} = \left(\frac{4V}{.9\pi\rho_V U}\right)^{\frac{1}{2}}$$

$$\mathrm{H} = HeadSpace + \left(N_{Trays} - 1\right) * TraySpacing + \mathrm{SumpSpace}$$

U_f= flooding velocity (ft/s)
C_{SB} = flooding correlation
F_{ST} = surface tension
σ = surface tension of liquid (dyne/cm)
F_F = foaming factor
F_{HA} = hole area factor
ρ_V = density of the vapor phase (lb/ft^3)
ρ_L = density of the liquid phase (lb/ft^3)
L = liquid volumetric flow rate (ft^3/s)
V = vapor volumetric flow rate (ft^3/s)
D = diameter (ft)

Appendix B: Aspen Plus Input Summary, Block Report and Stream Report

Flowsheet



Input Summary

```
                                        ~APD8F9.txt
;
;Input Summary created by Aspen Plus Rel. 34.0 at 12:33:54 Tue Apr 5, 2016
;Directory \\base\root\homedir  Filename
C:\Users\jayrao\AppData\Local\Temp\~apd8f9.txt
;


DYNAMICS
    DYNAMICS RESULTS=ON

IN-UNITS ENG

DEF-STREAMS CONVEN ALL

MODEL-OPTION

DATABANKS 'APV88 PURE32' / 'APV88 AQUEOUS' / 'APV88 SOLIDS' /  &
        'APV88 INORGANIC' / 'APEOSV88 AP-EOS' / NOASPENPCD

PROP-SOURCES 'APV88 PURE32' / 'APV88 AQUEOUS' / 'APV88 SOLIDS' &
         / 'APV88 INORGANIC' / 'APEOSV88 AP-EOS'

COMPONENTS
    PROPANE C3H8 /
    PROPENE C3H6-2 /
    HYDROGEN H2 /
    OXYGEN O2 /
    WATER H2O /
    CO CO /
    CO2 CO2 /
    METHANE CH4 /
    ETHANE C2H6 /
    ETHENE C2H4

SOLVE
    RUN-MODE MODE=SIM

FLOWSHEET
    BLOCK HX101 IN=S110 S105 OUT=S111 S15
    BLOCK H101 IN=S102 S9 S16 OUT=S104
    BLOCK MX102 IN=S104 S103 S314 OUT=S105
    BLOCK C202 IN=S206 OUT=S207
    BLOCK C201 IN=S205 OUT=S206
    BLOCK AD201 IN=S114 OUT=S203 S202
    BLOCK MEA201 IN=S203 OUT=S204 S205
    BLOCK DC201 IN=S207 OUT=3 S301
    BLOCK H103 IN=S112 OUT=S114 S1
    BLOCK T101 IN=S111 OUT=S112
    BLOCK H302 IN=S315 OUT=S316
    BLOCK HX301 IN=S309 S304 OUT=S315 S305
    BLOCK C303 IN=S308 OUT=S309
    BLOCK C302 IN=S307 OUT=S308
    BLOCK H301 IN=S305 OUT=S306
    BLOCK P301 IN=S303 OUT=S304
    BLOCK DC301 IN=S301 OUT=S303 S302
    BLOCK M301 IN=S306 OUT=S307 S310
    BLOCK MX301 IN=S311 S4 OUT=S312
    BLOCK C304 IN=S313 OUT=S314
    BLOCK H303 IN=RECY OUT=S313
    BLOCK C301 IN=S310 OUT=S311
    BLOCK MX101 IN=S101 S116 OUT=S102
    BLOCK B1 IN=S312 OUT=RECY PURGE
    BLOCK SP101 IN=S1 OUT=S3 2
                                        Page 1
```

```
    BLOCK P101 IN=2 OUT=S116
    BLOCK R101 IN=S15 OUT=S108
    BLOCK R102 IN=S108 S109 OUT=1 S2
    BLOCK B6 IN=S302 OUT=S4
    BLOCK H000 IN=1 S2 OUT=S110
    BLOCK B2 IN=3 PURGE S7 OUT=S6 S8
    BLOCK B3 IN=S8 OUT=S9 S10 S11 S12 S13 S14

PROPERTIES UNIQUAC

DEF-STREAMS CONVEN S102 2 1 3

PROP-SET PS-1 TEMP PRES HFLMX UNITS='F' 'psia' 'Btu/hr'  &
       SUBSTREAM=MIXED

STREAM 3
    SUBSTREAM MIXED TEMP=70. PRES=14.7
    MOLE-FLOW OXYGEN 7000.

STREAM S7
    SUBSTREAM MIXED TEMP=70. PRES=14.7
    MOLE-FLOW OXYGEN 7000.

STREAM S101
    SUBSTREAM MIXED TEMP=77.00000000 PRES=72.51886887
    MOLE-FLOW WATER 1873.929229

STREAM S103
    SUBSTREAM MIXED TEMP=77.00000000 PRES=72.51886887
    MOLE-FLOW PROPANE 4883.239107

STREAM S104
    SUBSTREAM MIXED TEMP=1094.000000 PRES=72.51886887
    MOLE-FLOW WATER 9592.313028

STREAM S105
    SUBSTREAM MIXED TEMP=470.6569292 PRES=72.51886887
    MOLE-FLOW PROPANE 5594.987588 / PROPENE .0124797561 /  &
        WATER 9595.203795

STREAM S109
    SUBSTREAM MIXED TEMP=1094.000000 PRES=73.00000000
    MOLE-FLOW OXYGEN 750.0000000

STREAM S110
    SUBSTREAM MIXED TEMP=1094.000000 PRES=72.51886887
    MOLE-FLOW PROPANE 2732.000000 / PROPENE 2798.874593 /  &
        HYDROGEN 1726.233812 / OXYGEN 45.14412842 / WATER  &
        10792.15506 / CO 50.15846695 / CO2 50.00799176 /  &
        METHANE 30.77442683 / ETHANE 9.232328070 / ETHENE  &
        21.54209882

STREAM S111
    SUBSTREAM MIXED TEMP=570.0383492 PRES=72.51886887
    MOLE-FLOW PROPANE 2732.000000 / PROPENE 2798.874593 /  &
        HYDROGEN 1726.233812 / OXYGEN 45.14412842 / WATER  &
        10792.15506 / CO 50.15846695 / CO2 50.00799176 /  &
        METHANE 30.77442683 / ETHANE 9.232328070 / ETHENE  &
        21.54209882

STREAM S112
    SUBSTREAM MIXED TEMP=457.3765616 PRES=34.80905705
    MOLE-FLOW PROPANE 2390.492724 / PROPENE 2449.015269 /  &
```

```
        HYDROGEN 1510.454585 / OXYGEN 39.50111220 / WATER  &
        9443.135673 / CO 43.88865867 / CO2 43.75699265 /  &
        METHANE 26.92762358 / ETHANE 8.078287053 / ETHENE  &
        18.84933649

STREAM S114
    SUBSTREAM MIXED TEMP=176.0000000 PRES=34.80905705
    MOLE-FLOW PROPANE 7515.089903 / PROPENE 11378.34025 /  &
        HYDROGEN 2993.952830 / WATER 14411.37866 / CO  &
        68.20321581 / CO2 46.09549429 / METHANE 43.66554116 /  &
        ETHANE 14.34564435 / ETHENE 31.13185524

STREAM S116
    SUBSTREAM MIXED TEMP=80.00000000 PRES=34.80905705
    MOLE-FLOW PROPANE 365.9795997 / PROPENE 311.8183337 /  &
        HYDROGEN .5746443619 / OXYGEN .1697640051 / WATER  &
        9361.705820 / CO .1415510488 / CO2 1.651896446 /  &
        METHANE .2052380544 / ETHANE .3803234697 / ETHENE  &
        .5618458728

STREAM S202
    SUBSTREAM MIXED TEMP=80.00000000 PRES=34.80905705
    MOLE-FLOW WATER 77.35835349 / CO 43.74710756 / CO2  &
        42.10509626 / METHANE .2672238556 / ETHANE .0769796357 / &
        ETHENE 18.28749062

STREAM S203
    SUBSTREAM MIXED TEMP=80.00000000 PRES=34.80905705
    MOLE-FLOW PROPANE 2024.512890 / PROPENE 2137.196845 /  &
        HYDROGEN 1509.879873 / OXYGEN 39.33135582 / WATER  &
        4.071492031 / METHANE 26.45516083 / ETHANE 7.620983704

STREAM S204
    SUBSTREAM MIXED TEMP=80.00000000 PRES=34.80905705
    MOLE-FLOW HYDROGEN 1.509879873 / WATER 1.180732690

STREAM S205
    SUBSTREAM MIXED TEMP=80.00000000 PRES=34.80905705
    MOLE-FLOW PROPANE 2024.512890 / PROPENE 2137.196845 /  &
        HYDROGEN 1508.369993 / OXYGEN 39.33135582 / WATER  &
        2.890759340 / METHANE 26.45516083 / ETHANE 7.620983704

STREAM S206
    SUBSTREAM MIXED TEMP=166.7917980 PRES=78.00000000
    MOLE-FLOW PROPANE 2024.512890 / PROPENE 2137.196845 /  &
        HYDROGEN 1508.369993 / OXYGEN 39.33135582 / WATER  &
        2.890759340 / METHANE 26.45516083 / ETHANE 7.620983704

STREAM S207
    SUBSTREAM MIXED TEMP=298.0887764 PRES=250.0000000
    MOLE-FLOW PROPANE 2024.512890 / PROPENE 2137.196845 /  &
        HYDROGEN 1508.369993 / OXYGEN 39.33135582 / WATER  &
        2.890759340 / METHANE 26.45516083 / ETHANE 7.620983704

STREAM S301
    SUBSTREAM MIXED TEMP=112.3483237 PRES=241.9800000
    MOLE-FLOW PROPANE 2010.661171 / PROPENE 1744.186738 /  &
        HYDROGEN 5.94247871E-6 / OXYGEN 1.74824656E-4 / WATER  &
        2.890759340 / METHANE 7.26307830E-4 / ETHANE  &
        .0688081146

STREAM S303
    SUBSTREAM MIXED TEMP=106.2000000 PRES=225.0000000
```

```
    MOLE-FLOW PROPANE 1898.027354 / PROPENE 1744.174259 /  &
        HYDROGEN 5.94247871E-6 / OXYGEN 1.74824656E-4 /  &
        METHANE 7.26307830E-4 / ETHANE .0688081146

STREAM S304
    SUBSTREAM MIXED TEMP=108.8871559 PRES=521.0000000
    MOLE-FLOW PROPANE 1898.027354 / PROPENE 1744.174259 /  &
        HYDROGEN 5.94247871E-6 / OXYGEN 1.74824656E-4 /  &
        METHANE 7.26307830E-4 / ETHANE .0688081146

STREAM S305
    SUBSTREAM MIXED TEMP=115.5200000 PRES=521.0000000
    MOLE-FLOW PROPANE 1898.027354 / PROPENE 1744.174259 /  &
        HYDROGEN 5.94247871E-6 / OXYGEN 1.74824656E-4 /  &
        METHANE 7.26307830E-4 / ETHANE .0688081146

STREAM S306
    SUBSTREAM MIXED TEMP=179.0000000 PRES=521.0000000
    MOLE-FLOW PROPANE 1898.027354 / PROPENE 1744.174259 /  &
        HYDROGEN 5.94247871E-6 / OXYGEN 1.74824656E-4 /  &
        METHANE 7.26307830E-4 / ETHANE .0688081146

STREAM S307
    SUBSTREAM MIXED TEMP=179.0000000 PRES=521.0000000
    MOLE-FLOW PROPANE 13.61769511 / PROPENE 1744.192306 /  &
        HYDROGEN 5.94265287E-6 / OXYGEN 1.74824171E-4 /  &
        METHANE 7.26327165E-4 / ETHANE .0688098111

STREAM S308
    SUBSTREAM MIXED TEMP=26.20599800 PRES=20.00000000
    MOLE-FLOW PROPANE 13.61769511 / PROPENE 1744.192306 /  &
        HYDROGEN 5.94265287E-6 / OXYGEN 1.74824171E-4 /  &
        METHANE 7.26327165E-4 / ETHANE .0688098111

STREAM S309
    SUBSTREAM MIXED TEMP=262.6361348 PRES=250.0000000
    MOLE-FLOW PROPANE 13.61769511 / PROPENE 1744.192306 /  &
        HYDROGEN 5.94265287E-6 / OXYGEN 1.74824171E-4 /  &
        METHANE 7.26327165E-4 / ETHANE .0688098111

STREAM S315
    SUBSTREAM MIXED TEMP=232.6643240 PRES=250.0000000
    MOLE-FLOW PROPANE 13.61769511 / PROPENE 1744.192306 /  &
        HYDROGEN 5.94265287E-6 / OXYGEN 1.74824171E-4 /  &
        METHANE 7.26327165E-4 / ETHANE .0688098111

STREAM S316
    SUBSTREAM MIXED TEMP=100.0000000 PRES=250.0000000
    MASS-FLOW PROPANE 13.61769511 / PROPENE 1744.192306 /  &
        HYDROGEN 5.94265287E-6 / OXYGEN 1.74824171E-4 /  &
        METHANE 7.26327165E-4 / ETHANE .0688098111

DEF-STREAMS HEAT S2

DEF-STREAMS HEAT S8

DEF-STREAMS HEAT S9

DEF-STREAMS HEAT S10

DEF-STREAMS HEAT S11

DEF-STREAMS HEAT S12
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```
DEF-STREAMS HEAT S13

DEF-STREAMS HEAT S14

DEF-STREAMS HEAT S16

STREAM S16
    INFO HEAT DUTY=165000000.

BLOCK MX101 MIXER
    PARAM

BLOCK MX102 MIXER
    PARAM

BLOCK MX301 MIXER
    PARAM

BLOCK B1 FSPLIT
    FRAC RECY 0.9

BLOCK B3 FSPLIT
    DUTY S10 53006618.9 / S11 220341562. / S12 54314968. /  &
        S13 11345144.9 / S14 161962246.

BLOCK SP101 FSPLIT
    FRAC S3 0.1

BLOCK AD201 SEP
    PARAM
    FRAC STREAM=S202 SUBSTREAM=MIXED COMPS=PROPANE PROPENE  &
        HYDROGEN OXYGEN WATER CO CO2 METHANE ETHANE ETHENE  &
        FRACS=0. 0. 0. 0. 0.95 0. 0. 0.01 0.01 0.

BLOCK M301 SEP
    PARAM
    MOLE-FLOW STREAM=S307 SUBSTREAM=MIXED COMPS=PROPANE  &
        PROPENE FLOWS=21.03801465 4186.578359

BLOCK MEA201 SEP
    PARAM
    FRAC STREAM=S204 SUBSTREAM=MIXED COMPS=PROPANE PROPENE  &
        HYDROGEN OXYGEN WATER CO CO2 METHANE ETHANE ETHENE  &
        FRACS=0. 0. 0.001 0. 0.29 0. 0.94 0. 0. 0.

BLOCK H000 HEATER
    PARAM PRES=52.5 DPPARMOPT=NO

BLOCK H101 HEATER
    PARAM PRES=72.51886887 NPHASE=2 DPPARMOPT=NO
    BLOCK-OPTION FREE-WATER=NO

BLOCK H103 HEATER
    PARAM TEMP=176.0000000 PRES=34.80905705 DPPARMOPT=NO
    BLOCK-OPTION FREE-WATER=YES

BLOCK H301 HEATER
    PARAM TEMP=257.0000000 PRES=575.0000000 DPPARMOPT=NO

BLOCK H302 HEATER
    PARAM TEMP=100.0000000 PRES=250.0000000 DPPARMOPT=NO
```

```
BLOCK H303 HEATER
    PARAM TEMP=71.60000000 PRES=20.00000000 DPPARMOPT=NO

BLOCK HX101 HEATX
    PARAM T-COLD=1094. PRES-HOT=52.50000000 MIN-TAPP=18.00000000
    FEEDS HOT=S110 COLD=S105
    OUTLETS-HOT S111
    OUTLETS-COLD S15
    HOT-SIDE DP-OPTION=CONSTANT DPPARMOPT=NO
    COLD-SIDE DPPARMOPT=NO
    TQ-PARAM CURVE=YES

BLOCK HX301 HEATX
    PARAM DUTY=1000000. CALC-TYPE=DESIGN MIN-TAPP=7.000000000  &
        U-OPTION=PHASE F-OPTION=CONSTANT CALC-METHOD=SHORTCUT
    FEEDS HOT=S309 COLD=S304
    OUTLETS-HOT S315
    OUTLETS-COLD S305
    HOT-SIDE DP-OPTION=CONSTANT DPPARMOPT=NO
    COLD-SIDE DP-OPTION=CONSTANT DPPARMOPT=NO
    TQ-PARAM CURVE=YES

BLOCK DC201 RADFRAC
    PARAM NSTAGE=20 ALGORITHM=STANDARD MAXOL=100 DAMPING=NONE
    COL-CONFIG CONDENSER=PARTIAL-V
    FEEDS S207 19
    PRODUCTS S301 20 L / 3 1 V
    P-SPEC 1 270.0000000
    COL-SPECS DP-STAGE=.1100000000 MOLE-D=3472.280629 MOLE-RR=4.5  &
        DP-COND=10.00000000
    TRAY-SIZE 1 2 19 FLEXI NPASS=4

BLOCK DC301 RADFRAC
    PARAM NSTAGE=90 ALGORITHM=STANDARD MAXOL=25 DAMPING=NONE
    COL-CONFIG CONDENSER=TOTAL
    FEEDS S301 45
    PRODUCTS S303 1 L / S302 90 L
    P-SPEC 1 225.0000000
    COL-SPECS DP-STAGE=.1100000000 MOLE-D=6613.867866 MOLE-RR=5.  &
        DP-COND=10.00000000
    TRAY-SIZE 1 2 89 FLEXI NPASS=4

BLOCK B2 RSTOIC
    PARAM TEMP=1094. PRES=14.7 COMBUSTION=YES PROD-NOX=NO

BLOCK R101 RSTOIC
    PARAM TEMP=1094.000000 PRES=73.00000000 SERIES=YES
    STOIC 1 MIXED PROPANE -1. / PROPENE 1. / HYDROGEN 1.
    STOIC 2 MIXED PROPANE -1. / METHANE 1. / ETHENE 1.
    STOIC 3 MIXED ETHENE -1. / HYDROGEN -1. / ETHANE 1.
    CONV 1 MIXED PROPANE 0.313
    CONV 2 MIXED PROPANE 0.002
    CONV 3 MIXED ETHENE 0.3

BLOCK R102 RSTOIC
    PARAM TEMP=1094.000000 PRES=56.30000000 SERIES=YES
    STOIC 1 MIXED PROPANE -1. / PROPENE 1. / HYDROGEN 1.
    STOIC 2 MIXED PROPANE -1. / ETHENE 1. / METHANE 1.
    STOIC 3 MIXED PROPANE -1. / OXYGEN -5. / CO2 3. /  &
        WATER 4.
    STOIC 4 MIXED PROPANE -1. / OXYGEN -3.5 / CO 3. /  &
        WATER 4.
    STOIC 5 MIXED ETHENE -1. / HYDROGEN -1. / ETHANE 1.
```

```
    STOIC 6 MIXED HYDROGEN -1. / OXYGEN -0.5 / WATER 1.
    CONV 1 MIXED PROPANE 0.22375
    CONV 2 MIXED PROPANE 0.0011
    CONV 3 MIXED PROPANE 0.008
    CONV 4 MIXED PROPANE 0.004
    CONV 5 MIXED ETHENE 0.3
    EXTENT 6 983.9230761

BLOCK B6 PUMP
    PARAM PRES=20.00000000 PUMP-TYPE=TURBINE

BLOCK P101 PUMP
    PARAM PRES=72.51886887

BLOCK P301 PUMP
    PARAM PRES=575.0000000

BLOCK C201 COMPR
    PARAM TYPE=ISENTROPIC PRES=100.0000000 SB-MAXIT=30  &
        SB-TOL=0.0001

BLOCK C202 COMPR
    PARAM TYPE=ISENTROPIC PRES=300.0000000 SB-MAXIT=30  &
        SB-TOL=0.0001

BLOCK C301 COMPR
    PARAM TYPE=ISENTROPIC PRES=20.00000000 NPHASE=2 SB-MAXIT=30  &
        SB-TOL=0.0001  MODEL-TYPE=TURBINE
    BLOCK-OPTION FREE-WATER=NO

BLOCK C302 COMPR
    PARAM TYPE=ISENTROPIC PRES=20.00000000 NPHASE=2 SB-MAXIT=30  &
        SB-TOL=0.0001  MODEL-TYPE=TURBINE
    BLOCK-OPTION FREE-WATER=NO

BLOCK C303 COMPR
    PARAM TYPE=ISENTROPIC PRES=250.0000000 SB-MAXIT=30  &
        SB-TOL=0.0001  MODEL-TYPE=COMPRESSOR

BLOCK C304 COMPR
    PARAM TYPE=ISENTROPIC PRES=72.51886887 NPHASE=1 SB-MAXIT=30  &
        SB-TOL=0.0001  MODEL-TYPE=COMPRESSOR
    BLOCK-OPTION FREE-WATER=NO

BLOCK T101 COMPR
    PARAM TYPE=ISENTROPIC PRES=34.80905705 SB-MAXIT=30  &
        SB-TOL=0.0001  MODEL-TYPE=TURBINE

EO-CONV-OPTI

CONV-OPTIONS
    PARAM TOL=0.1

STREAM-REPOR MOLEFLOW MASSFLOW PROPERTIES=PS-1 INCL-STREAMS=S101  &
        S102 S103 S104 S105 S108 S109 S110 S111 S112 S114  &
        S116 S314

REACTIONS R-1 GENERAL
    REAC-DATA 1 NAME=DHYGROG REAC-CLASS=POWERLAW PHASE=V  &
        DELT=1080.000000 CBASIS=PARTIALPRES RBASIS=CAT-WT  &
        PRES-UNIT="BAR"
    REAC-DATA 3 NAME=SPLIT PHASE=V CBASIS=PARTIALPRES  &
        RBASIS=CAT-WT PRES-UNIT="BAR"
```

```
REAC-DATA 5 NAME=HYDROG REAC-CLASS=POWERLAW STATUS=ON
RATE-CON 1 PRE-EXP=0.015 ACT-ENERGY=25795.35684
RATE-CON 3 PRE-EXP=1E-005 ACT-ENERGY=17196.90456
RATE-CON 5 PRE-EXP=2E-005 ACT-ENERGY=21496.13069
STOIC 1 MIXED PROPANE -1. / HYDROGEN 1. / PROPENE 1.
STOIC 3 MIXED PROPANE -1. / METHANE 1. / ETHENE 1.
STOIC 5 MIXED ETHENE -1. / HYDROGEN -1. / ETHANE 1.
REAC-ACT 1 / 5
;
;
;
;
;
;
```

Block Report

```
                                    ~AP6A60.tmp

BLOCK:  AD201    MODEL: SEP
------------------------------
  INLET STREAM:          S114
  OUTLET STREAMS:        S203        S202
  PROPERTY OPTION SET:   UNIQUAC   UNIQUAC / IDEAL GAS

                      ***  MASS AND ENERGY BALANCE  ***
                                   IN               OUT         RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(LBMOL/HR)            13621.6          13621.6        -0.534147E-15
      MASS(LB/HR   )            433918.          433918.        -0.536578E-15
      ENTHALPY(BTU/HR  )     -0.244816E+09    -0.255166E+09     0.405609E-01

                      ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E             12430.4       LB/HR
   PRODUCT STREAMS CO2E          12430.4       LB/HR
   NET STREAMS CO2E PRODUCTION   0.00000       LB/HR
   UTILITIES CO2E PRODUCTION     0.00000       LB/HR
   TOTAL CO2E PRODUCTION         0.00000       LB/HR


                         ***  INPUT DATA  ***

  FLASH SPECS FOR STREAM S203
  TWO    PHASE  TP  FLASH
  PRESSURE DROP          PSI                                    0.0
  MAXIMUM NO. ITERATIONS                                       30
  CONVERGENCE TOLERANCE                                         0.000100000

  FLASH SPECS FOR STREAM S202
  TWO    PHASE  TP  FLASH
  PRESSURE DROP          PSI                                    0.0
  MAXIMUM NO. ITERATIONS                                       30
  CONVERGENCE TOLERANCE                                         0.000100000

  FRACTION OF FEED
    SUBSTREAM= MIXED
      STREAM= S202      CPT= PROPANE    FRACTION=          0.0
                             PROPENE                      0.0
                             HYDROGEN                     0.0
                             OXYGEN                       0.0
                             WATER                        0.95000
                             CO                           0.0
                             CO2                          0.0
                             METHANE                      0.0100000
                             ETHANE                       0.0100000
                             ETHENE                       0.0


                           ***  RESULTS  ***

  HEAT DUTY              BTU/HR                            -0.10350E+08

 COMPONENT = PROPANE
   STREAM     SUBSTREAM    SPLIT FRACTION
   S203       MIXED                1.00000

 COMPONENT = PROPENE
   STREAM     SUBSTREAM    SPLIT FRACTION
   S203       MIXED                1.00000

 COMPONENT = HYDROGEN
                                    Page 1
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```
  STREAM     SUBSTREAM    SPLIT FRACTION
  S203       MIXED                1.00000

 COMPONENT = WATER
  STREAM     SUBSTREAM    SPLIT FRACTION
  S203       MIXED                0.050000
  S202       MIXED                0.95000

 COMPONENT = CO
  STREAM     SUBSTREAM    SPLIT FRACTION
  S203       MIXED                1.00000

 COMPONENT = CO2
  STREAM     SUBSTREAM    SPLIT FRACTION
  S203       MIXED                1.00000

 COMPONENT = METHANE
  STREAM     SUBSTREAM    SPLIT FRACTION
  S203       MIXED                0.99000
  S202       MIXED                0.0100000

 COMPONENT = ETHANE
  STREAM     SUBSTREAM    SPLIT FRACTION
  S203       MIXED                0.99000
  S202       MIXED                0.0100000

 COMPONENT = ETHENE
  STREAM     SUBSTREAM    SPLIT FRACTION
  S203       MIXED                1.00000

BLOCK:  B1       MODEL: FSPLIT
------------------------------
  INLET STREAM:          S312
  OUTLET STREAMS:        RECY        PURGE
  PROPERTY OPTION SET:   UNIQUAC   UNIQUAC / IDEAL GAS

                     ***  MASS AND ENERGY BALANCE  ***
                                IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(LBMOL/HR)            5240.37         5240.37         0.00000
      MASS(LB/HR   )             229716.         229716.        0.00000
      ENTHALPY(BTU/HR  )      -0.227995E+09   -0.227995E+09     0.00000

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E             3.30868      LB/HR
   PRODUCT STREAMS CO2E          3.30868      LB/HR
   NET STREAMS CO2E PRODUCTION   0.00000      LB/HR
   UTILITIES CO2E PRODUCTION     0.00000      LB/HR
   TOTAL CO2E PRODUCTION         0.00000      LB/HR

                         ***  INPUT DATA  ***

 FRACTION OF FLOW                STRM=RECY     FRAC=         0.90000

                          ***  RESULTS  ***

 STREAM= RECY           SPLIT=          0.90000     KEY=  0    STREAM-ORDER=   1
         PURGE                          0.100000          0                    2

BLOCK:  B2       MODEL: RSTOIC
------------------------------
  INLET STREAMS:         3           PURGE       S7
  OUTLET STREAM:         S6
```

OUTLET HEAT STREAM: S8
PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS

*** MASS AND ENERGY BALANCE ***

	IN	OUT	GENERATION	RELATIVE DIFF.
TOTAL BALANCE				
MOLE(LBMOL/HR)	10996.3	9840.55	-1155.77	0.165418E-15
MASS(LB/HR)	258604.	258604.		0.00000
ENTHALPY(BTU/HR)	-0.315200E+08	-0.315200E+08		-0.472752E-15

*** CO2 EQUIVALENT SUMMARY ***

FEED STREAMS CO2E	7484.40	LB/HR
PRODUCT STREAMS CO2E	81040.3	LB/HR
NET STREAMS CO2E PRODUCTION	73555.9	LB/HR
UTILITIES CO2E PRODUCTION	0.00000	LB/HR
TOTAL CO2E PRODUCTION	73555.9	LB/HR

*** INPUT DATA ***

TWO PHASE TP FLASH		
SPECIFIED TEMPERATURE	F	1,094.00
SPECIFIED PRESSURE	PSIA	14.7000
MAXIMUM NO. ITERATIONS		30
CONVERGENCE TOLERANCE		0.000100000
SIMULTANEOUS REACTIONS		
GENERATE COMBUSTION REACTIONS FOR FEED SPECIES		YES
COMBUSTION PRODUCT FOR CHEMICALLY BOUND NITROGEN		NO

*** RESULTS ***

OUTLET TEMPERATURE	F	1094.0
OUTLET PRESSURE	PSIA	14.700
HEAT DUTY	BTU/HR	-0.77441E+09
VAPOR FRACTION		1.0000

COMBUSTION REACTIONS:

RXN NO	STOICHIOMETRY
C1	PROPANE + 5 OXYGEN --> 4 WATER + 3 CO2
C2	PROPENE + 4.5 OXYGEN --> 3 WATER + 3 CO2
C3	HYDROGEN + 0.5 OXYGEN --> WATER
C4	0.5 OXYGEN + CO --> CO2
C5	2 OXYGEN + METHANE --> 2 WATER + CO2
C6	3.5 OXYGEN + ETHANE --> 3 WATER + 2 CO2
C7	3 OXYGEN + ETHENE --> 2 WATER + 2 CO2

REACTION EXTENTS:

REACTION NUMBER	REACTION EXTENT LBMOL/HR
C1	483.58
C2	90.471
C3	3318.8
C4	58.370
C5	17.892
C6	8.0303
C7	9.9568

V-L PHASE EQUILIBRIUM :

COMP	F(I)	X(I)	Y(I)	K(I)
OXYGEN	0.24314	0.78058E-01	0.24314	6679.3
WATER	0.56974	0.88044	0.56974	1387.6
CO2	0.18713	0.41498E-01	0.18713	9669.6

BLOCK: B3 MODEL: FSPLIT

INLET STREAM: S8
OUTLET STREAMS: S9 S10 S11 S12 S13 S14
PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS

*** MASS AND ENERGY BALANCE ***

	IN	OUT	RELATIVE DIFF.
TOTAL BALANCE			
ENTHALPY(BTU/HR)	0.774410E+09	0.774410E+09	0.00000

*** RESULTS ***

STREAM= S9	SPLIT=	0.35309
S10		0.068448
S11		0.28453
S12		0.070137
S13		0.014650
S14		0.20914

BLOCK: B6 MODEL: PUMP

INLET STREAM: S302
OUTLET STREAM: S4
PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS

*** MASS AND ENERGY BALANCE ***

	IN	OUT	RELATIVE DIFF.
TOTAL BALANCE			
MOLE(LBMOL/HR)	2834.12	2834.12	0.00000
MASS(LB/HR)	124389.	124389.	0.233974E-15
ENTHALPY(BTU/HR)	-0.141655E+09	-0.141787E+09	0.934831E-03

*** CO2 EQUIVALENT SUMMARY ***

FEED STREAMS CO2E	0.00000	LB/HR
PRODUCT STREAMS CO2E	0.00000	LB/HR
NET STREAMS CO2E PRODUCTION	0.00000	LB/HR
UTILITIES CO2E PRODUCTION	0.00000	LB/HR
TOTAL CO2E PRODUCTION	0.00000	LB/HR

*** INPUT DATA ***

EQUIPMENT TYPE: TURBINE

OUTLET PRESSURE PSIA	20.0000
DRIVER EFFICIENCY	1.00000

FLASH SPECIFICATIONS:
LIQUID PHASE CALCULATION
NO FLASH PERFORMED

MAXIMUM NUMBER OF ITERATIONS	30
TOLERANCE	0.000100000

*** RESULTS ***

VOLUMETRIC FLOW RATE	CUFT/HR	4,416.56
PRESSURE CHANGE PSI		-224.680

NPSH AVAILABLE	FT-LBF/LB	0.0
FLUID POWER HP		-72.1682
BRAKE POWER HP		-52.0930
ELECTRICITY KW		-38.8457
PUMP EFFICIENCY USED		0.72183
NET WORK REQUIRED HP		-52.0930
HEAD DEVELOPED	FT-LBF/LB	-1,148.76

BLOCK: C201 MODEL: COMPR

INLET STREAM: S205
OUTLET STREAM: S206
PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS

*** MASS AND ENERGY BALANCE ***

	IN	OUT	RELATIVE DIFF.
TOTAL BALANCE			
MOLE(LBMOL/HR)	12920.3	12920.3	0.00000
MASS(LB/HR)	418458.	418458.	0.00000
ENTHALPY(BTU/HR)	-0.165617E+09	-0.140095E+09	-0.154101

*** CO2 EQUIVALENT SUMMARY ***

FEED STREAMS CO2E	7487.38	LB/HR
PRODUCT STREAMS CO2E	7487.38	LB/HR
NET STREAMS CO2E PRODUCTION	0.00000	LB/HR
UTILITIES CO2E PRODUCTION	0.00000	LB/HR
TOTAL CO2E PRODUCTION	0.00000	LB/HR

*** INPUT DATA ***

ISENTROPIC CENTRIFUGAL COMPRESSOR

OUTLET PRESSURE PSIA		100.000
ISENTROPIC EFFICIENCY		0.72000
MECHANICAL EFFICIENCY		1.00000

*** RESULTS ***

INDICATED HORSEPOWER REQUIREMENT	HP	10,030.4
BRAKE HORSEPOWER REQUIREMENT	HP	10,030.4
NET WORK REQUIRED	HP	10,030.4
POWER LOSSES	HP	0.0
ISENTROPIC HORSEPOWER REQUIREMENT	HP	7,221.88
CALCULATED OUTLET TEMP F		294.195
ISENTROPIC TEMPERATURE F		262.506
EFFICIENCY (POLYTR/ISENTR) USED		0.72000
OUTLET VAPOR FRACTION		1.00000
HEAD DEVELOPED, FT-LBF/LB		34,171.5
MECHANICAL EFFICIENCY USED		1.00000
INLET HEAT CAPACITY RATIO		1.14507
INLET VOLUMETRIC FLOW RATE , CUFT/HR		2,532,020.
OUTLET VOLUMETRIC FLOW RATE, CUFT/HR		1,045,250.
INLET COMPRESSIBILITY FACTOR		1.00000
OUTLET COMPRESSIBILITY FACTOR		1.00000
AV. ISENT. VOL. EXPONENT		1.13753
AV. ISENT. TEMP EXPONENT		1.13753
AV. ACTUAL VOL. EXPONENT		1.19275
AV. ACTUAL TEMP EXPONENT		1.19275

BLOCK: C202 MODEL: COMPR

INLET STREAM: S206
OUTLET STREAM: S207
PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS

```
                    ***  MASS AND ENERGY BALANCE  ***
                                 IN              OUT        RELATIVE DIFF.
 TOTAL BALANCE
    MOLE(LBMOL/HR)            12920.3         12920.3          0.00000
    MASS(LB/HR   )            418458.         418458.          0.00000
    ENTHALPY(BTU/HR  )     -0.140095E+09   -0.108743E+09    -0.223788

                    ***  CO2 EQUIVALENT SUMMARY ***
 FEED STREAMS CO2E             7487.38      LB/HR
 PRODUCT STREAMS CO2E          7487.38      LB/HR
 NET STREAMS CO2E PRODUCTION   0.00000      LB/HR
 UTILITIES CO2E PRODUCTION     0.00000      LB/HR
 TOTAL CO2E PRODUCTION         0.00000      LB/HR

                         ***  INPUT DATA  ***

ISENTROPIC CENTRIFUGAL COMPRESSOR
 OUTLET PRESSURE  PSIA                                    300.000
 ISENTROPIC EFFICIENCY                                      0.72000
 MECHANICAL EFFICIENCY                                      1.00000

                         ***  RESULTS  ***

 INDICATED  HORSEPOWER REQUIREMENT  HP              12,321.7
 BRAKE      HORSEPOWER REQUIREMENT  HP              12,321.7
 NET WORK REQUIRED                  HP              12,321.7
 POWER LOSSES                       HP                   0.0
 ISENTROPIC HORSEPOWER REQUIREMENT  HP               8,871.59
 CALCULATED OUTLET TEMP  F                             423.422
 ISENTROPIC TEMPERATURE  F                             388.640
 EFFICIENCY (POLYTR/ISENTR) USED                         0.72000
 OUTLET VAPOR FRACTION                                   1.00000
 HEAD DEVELOPED,       FT-LBF/LB                    41,977.3
 MECHANICAL EFFICIENCY USED                              1.00000
 INLET HEAT CAPACITY RATIO                               1.12635
 INLET VOLUMETRIC FLOW RATE , CUFT/HR             1,045,250.
 OUTLET VOLUMETRIC FLOW RATE, CUFT/HR               408,144.
 INLET  COMPRESSIBILITY FACTOR                           1.00000
 OUTLET COMPRESSIBILITY FACTOR                           1.00000
 AV. ISENT. VOL. EXPONENT                                1.12037
 AV. ISENT. TEMP EXPONENT                                1.12037
 AV. ACTUAL VOL. EXPONENT                                1.16824
 AV. ACTUAL TEMP EXPONENT                                1.16824

BLOCK:  C301     MODEL: COMPR
------------------------------
  INLET STREAM:          S310
  OUTLET STREAM:         S311
  PROPERTY OPTION SET:   UNIQUAC   UNIQUAC / IDEAL GAS

                    ***  MASS AND ENERGY BALANCE  ***
                                 IN              OUT        RELATIVE DIFF.
 TOTAL BALANCE
    MOLE(LBMOL/HR)            2406.25         2406.25          0.00000
    MASS(LB/HR   )            105327.         105327.          0.00000
    ENTHALPY(BTU/HR  )     -0.791716E+08   -0.862080E+08     0.816211E-01

                    ***  CO2 EQUIVALENT SUMMARY ***
 FEED STREAMS CO2E             3.30868      LB/HR
 PRODUCT STREAMS CO2E          3.30868      LB/HR
 NET STREAMS CO2E PRODUCTION   0.00000      LB/HR
 UTILITIES CO2E PRODUCTION     0.00000      LB/HR
```

TOTAL CO2E PRODUCTION 0.00000 LB/HR

*** INPUT DATA ***

ISENTROPIC TURBINE

OUTLET PRESSURE PSIA	20.0000
ISENTROPIC EFFICIENCY	0.72000
MECHANICAL EFFICIENCY	1.00000

*** RESULTS ***

INDICATED HORSEPOWER REQUIREMENT	HP	-2,765.41
BRAKE HORSEPOWER REQUIREMENT	HP	-2,765.41
NET WORK REQUIRED	HP	-2,765.41
POWER LOSSES	HP	0.0
ISENTROPIC HORSEPOWER REQUIREMENT	HP	-3,840.84
CALCULATED OUTLET TEMP F		109.977
ISENTROPIC TEMPERATURE F		44.1026
EFFICIENCY (POLYTR/ISENTR) USED		0.72000
OUTLET VAPOR FRACTION		1.00000
HEAD DEVELOPED, FT-LBF/LB		-72,202.6
MECHANICAL EFFICIENCY USED		1.00000
INLET HEAT CAPACITY RATIO		1.10048
INLET VOLUMETRIC FLOW RATE , CUFT/HR		32,184.7
OUTLET VOLUMETRIC FLOW RATE, CUFT/HR		735,485.
INLET COMPRESSIBILITY FACTOR		1.00000
OUTLET COMPRESSIBILITY FACTOR		1.00000
AV. ISENT. VOL. EXPONENT		1.11726
AV. ISENT. TEMP EXPONENT		1.11726
AV. ACTUAL VOL. EXPONENT		1.07338
AV. ACTUAL TEMP EXPONENT		1.07338

BLOCK: C302 MODEL: COMPR

INLET STREAM: S307
OUTLET STREAM: S308
PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS

*** MASS AND ENERGY BALANCE ***

	IN	OUT	RELATIVE DIFF.
TOTAL BALANCE			
MOLE(LBMOL/HR)	4207.62	4207.62	0.00000
MASS(LB/HR)	177102.	177102.	0.00000
ENTHALPY(BTU/HR)	0.486057E+08	0.365641E+08	0.247740

*** CO2 EQUIVALENT SUMMARY ***

FEED STREAMS CO2E	0.00000	LB/HR
PRODUCT STREAMS CO2E	0.00000	LB/HR
NET STREAMS CO2E PRODUCTION	0.00000	LB/HR
UTILITIES CO2E PRODUCTION	0.00000	LB/HR
TOTAL CO2E PRODUCTION	0.00000	LB/HR

*** INPUT DATA ***

ISENTROPIC TURBINE

OUTLET PRESSURE PSIA	20.0000
ISENTROPIC EFFICIENCY	0.72000
MECHANICAL EFFICIENCY	1.00000

*** RESULTS ***

INDICATED HORSEPOWER REQUIREMENT	HP	-4,732.51
BRAKE HORSEPOWER REQUIREMENT	HP	-4,732.51

NET WORK REQUIRED	HP	-4,732.51
POWER LOSSES	HP	0.0
ISENTROPIC HORSEPOWER REQUIREMENT	HP	-6,572.93
CALCULATED OUTLET TEMP F		93.6757
ISENTROPIC TEMPERATURE F		19.7165
EFFICIENCY (POLYTR/ISENTR) USED		0.72000
OUTLET VAPOR FRACTION		1.00000
HEAD DEVELOPED, FT-LBF/LB		-73,485.6
MECHANICAL EFFICIENCY USED		1.00000
INLET HEAT CAPACITY RATIO		1.11580
INLET VOLUMETRIC FLOW RATE , CUFT/HR		56,278.7
OUTLET VOLUMETRIC FLOW RATE, CUFT/HR		1,249,280.
INLET COMPRESSIBILITY FACTOR		1.00000
OUTLET COMPRESSIBILITY FACTOR		1.00000
AV. ISENT. VOL. EXPONENT		1.13601
AV. ISENT. TEMP EXPONENT		1.13601
AV. ACTUAL VOL. EXPONENT		1.08343
AV. ACTUAL TEMP EXPONENT		1.08343

BLOCK: C303 MODEL: COMPR

INLET STREAM:	S308
OUTLET STREAM:	S309
PROPERTY OPTION SET:	UNIQUAC UNIQUAC / IDEAL GAS

*** MASS AND ENERGY BALANCE ***

	IN	OUT	RELATIVE DIFF.
TOTAL BALANCE			
MOLE(LBMOL/HR)	4207.62	4207.62	0.00000
MASS(LB/HR)	177102.	177102.	0.00000
ENTHALPY(BTU/HR)	0.365641E+08	0.554198E+08	-0.340234

*** CO2 EQUIVALENT SUMMARY ***

FEED STREAMS CO2E	0.00000	LB/HR
PRODUCT STREAMS CO2E	0.00000	LB/HR
NET STREAMS CO2E PRODUCTION	0.00000	LB/HR
UTILITIES CO2E PRODUCTION	0.00000	LB/HR
TOTAL CO2E PRODUCTION	0.00000	LB/HR

*** INPUT DATA ***

ISENTROPIC CENTRIFUGAL COMPRESSOR

OUTLET PRESSURE PSIA	250.000
ISENTROPIC EFFICIENCY	0.72000
MECHANICAL EFFICIENCY	1.00000

*** RESULTS ***

INDICATED HORSEPOWER REQUIREMENT	HP	7,410.58
BRAKE HORSEPOWER REQUIREMENT	HP	7,410.58
NET WORK REQUIRED	HP	7,410.58
POWER LOSSES	HP	0.0
ISENTROPIC HORSEPOWER REQUIREMENT	HP	5,335.62
CALCULATED OUTLET TEMP F		338.266
ISENTROPIC TEMPERATURE F		275.862
EFFICIENCY (POLYTR/ISENTR) USED		0.72000
OUTLET VAPOR FRACTION		1.00000
HEAD DEVELOPED, FT-LBF/LB		59,652.3
MECHANICAL EFFICIENCY USED		1.00000
INLET HEAT CAPACITY RATIO		1.14352
INLET VOLUMETRIC FLOW RATE , CUFT/HR		1,249,280.
OUTLET VOLUMETRIC FLOW RATE, CUFT/HR		144,119.
INLET COMPRESSIBILITY FACTOR		1.00000

OUTLET COMPRESSIBILITY FACTOR	1.00000
AV. ISENT. VOL. EXPONENT	1.12700
AV. ISENT. TEMP EXPONENT	1.12700
AV. ACTUAL VOL. EXPONENT	1.16949
AV. ACTUAL TEMP EXPONENT	1.16949

BLOCK: C304 MODEL: COMPR

INLET STREAM: S313
OUTLET STREAM: S314
PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS

*** MASS AND ENERGY BALANCE ***

	IN	OUT	RELATIVE DIFF.
TOTAL BALANCE			
MOLE(LBMOL/HR)	4716.34	4716.34	0.00000
MASS(LB/HR)	206744.	206744.	0.00000
ENTHALPY(BTU/HR)	-0.194699E+09	-0.185129E+09	-0.491510E-01

*** CO2 EQUIVALENT SUMMARY ***

FEED STREAMS CO2E	2.97781	LB/HR
PRODUCT STREAMS CO2E	2.97781	LB/HR
NET STREAMS CO2E PRODUCTION	0.00000	LB/HR
UTILITIES CO2E PRODUCTION	0.00000	LB/HR
TOTAL CO2E PRODUCTION	0.00000	LB/HR

*** INPUT DATA ***

GAS PHASE CALCULATION
NO FLASH PERFORMED
ISENTROPIC CENTRIFUGAL COMPRESSOR

OUTLET PRESSURE PSIA	72.5189
ISENTROPIC EFFICIENCY	0.72000
MECHANICAL EFFICIENCY	1.00000

*** RESULTS ***

INDICATED HORSEPOWER REQUIREMENT	HP	3,761.01
BRAKE HORSEPOWER REQUIREMENT	HP	3,761.01
NET WORK REQUIRED	HP	3,761.01
POWER LOSSES	HP	0.0
ISENTROPIC HORSEPOWER REQUIREMENT	HP	2,707.93
CALCULATED OUTLET TEMP F		180.707
ISENTROPIC TEMPERATURE F		151.728
EFFICIENCY (POLYTR/ISENTR) USED		0.72000
OUTLET VAPOR FRACTION		1.00000
HEAD DEVELOPED, FT-LBF/LB		25,933.9
MECHANICAL EFFICIENCY USED		1.00000
INLET HEAT CAPACITY RATIO		1.13007
INLET VOLUMETRIC FLOW RATE , CUFT/HR		1,344,460.
OUTLET VOLUMETRIC FLOW RATE, CUFT/HR		446,936.
INLET COMPRESSIBILITY FACTOR		1.00000
OUTLET COMPRESSIBILITY FACTOR		1.00000
AV. ISENT. VOL. EXPONENT		1.12241
AV. ISENT. TEMP EXPONENT		1.12241
AV. ACTUAL VOL. EXPONENT		1.16960
AV. ACTUAL TEMP EXPONENT		1.16960

BLOCK: DC201 MODEL: RADFRAC

INLETS -	S207	STAGE 19
OUTLETS -	3	STAGE 1
	S301	STAGE 20

PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS

*** MASS AND ENERGY BALANCE ***

	IN	OUT	RELATIVE DIFF.
TOTAL BALANCE			
MOLE(LBMOL/HR)	12920.3	12920.3	-0.140786E-15
MASS(LB/HR)	418458.	418458.	0.421196E-12
ENTHALPY(BTU/HR)	-0.108743E+09	-0.230215E+09	0.527644

*** CO2 EQUIVALENT SUMMARY ***

FEED STREAMS CO2E	7487.38	LB/HR
PRODUCT STREAMS CO2E	7487.38	LB/HR
NET STREAMS CO2E PRODUCTION	0.00000	LB/HR
UTILITIES CO2E PRODUCTION	0.00000	LB/HR
TOTAL CO2E PRODUCTION	0.00000	LB/HR

****
**** INPUT DATA ****
****

**** INPUT PARAMETERS ****

NUMBER OF STAGES	20
ALGORITHM OPTION	STANDARD
ABSORBER OPTION	NO
INITIALIZATION OPTION	STANDARD
HYDRAULIC PARAMETER CALCULATIONS	NO
INSIDE LOOP CONVERGENCE METHOD	BROYDEN
DESIGN SPECIFICATION METHOD	NESTED
MAXIMUM NO. OF OUTSIDE LOOP ITERATIONS	100
MAXIMUM NO. OF INSIDE LOOP ITERATIONS	10
MAXIMUM NUMBER OF FLASH ITERATIONS	30
FLASH TOLERANCE	0.000100000
OUTSIDE LOOP CONVERGENCE TOLERANCE	0.000100000

**** COL-SPECS ****

MOLAR VAPOR DIST / TOTAL DIST		1.00000
MOLAR REFLUX RATIO		4.50000
MOLAR DISTILLATE RATE	LBMOL/HR	3,472.28

**** PROFILES ****

P-SPEC	STAGE 1	PRES, PSIA	270.000

****
**** RESULTS ****
****

*** COMPONENT SPLIT FRACTIONS ***

	OUTLET STREAMS	
	3	S301
COMPONENT:		
PROPANE	.27960E-03	.99972
PROPENE	.10976E-01	.98902
HYDROGEN	1.0000	.19974E-07
WATER	0.0000	1.0000
CO	.99999	.95697E-05

CO2	.99189	.81120E-02
METHANE	.99989	.10963E-03
ETHANE	.97478	.25220E-01
ETHENE	.99296	.70441E-02

*** SUMMARY OF KEY RESULTS ***

TOP STAGE TEMPERATURE	F	-96.1354
BOTTOM STAGE TEMPERATURE	F	124.846
TOP STAGE LIQUID FLOW	LBMOL/HR	15,625.3
BOTTOM STAGE LIQUID FLOW	LBMOL/HR	9,447.99
TOP STAGE VAPOR FLOW	LBMOL/HR	3,472.28
BOILUP VAPOR FLOW	LBMOL/HR	10,557.1
MOLAR REFLUX RATIO		4.50000
MOLAR BOILUP RATIO		1.11739
CONDENSER DUTY (W/O SUBCOOL)	BTU/HR	-0.176457+09
REBOILER DUTY	BTU/HR	0.549858+08

**** MAXIMUM FINAL RELATIVE ERRORS ****

DEW POINT	0.31126E-13	STAGE= 2	
BUBBLE POINT	0.12848E-10	STAGE= 2	
COMPONENT MASS BALANCE	0.70224E-10	STAGE= 2	COMP=HYDROGEN
ENERGY BALANCE	0.54293E-11	STAGE= 1	

**** PROFILES ****

NOTE REPORTED VALUES FOR STAGE LIQUID AND VAPOR RATES ARE THE FLOWS FROM THE STAGE INCLUDING ANY SIDE PRODUCT.

STAGE	TEMPERATURE F	PRESSURE PSIA	ENTHALPY BTU/LBMOL LIQUID	ENTHALPY BTU/LBMOL VAPOR	HEAT DUTY BTU/HR
1	-96.135	270.00	-7339.6	-2412.6	-.17646+09
2	97.617	280.00	368.84	2796.0	
16	114.01	281.54	-16909.	-8353.5	
17	114.74	281.65	-19316.	-10445.	
18	115.58	281.76	-21884.	-12615.	
19	124.26	281.87	-22071.	-14311.	
20	124.85	281.98	-23480.	-15602.	.54986+08

STAGE	FLOW RATE LBMOL/HR LIQUID	FLOW RATE LBMOL/HR VAPOR	FEED RATE LBMOL/HR LIQUID	FEED RATE LBMOL/HR VAPOR	FEED RATE LBMOL/HR MIXED	PRODUCT RATE LBMOL/HR LIQUID	PRODUCT RATE LBMOL/HR VAPOR
1	0.1563E+05	3472.					3472.2806
2	0.2968E+05	0.1910E+05					
16	0.3161E+05	0.3507E+05					
17	0.3162E+05	0.3509E+05					
18	0.1870E+05	0.3509E+05		.12920+05			
19	0.2001E+05	9252.					
20	9448.	0.1056E+05				9447.9886	

**** MASS FLOW PROFILES ****

STAGE	FLOW RATE LB/HR LIQUID	FLOW RATE LB/HR VAPOR	FEED RATE LB/HR LIQUID	FEED RATE LB/HR VAPOR	FEED RATE LB/HR MIXED	PRODUCT RATE LB/HR LIQUID	PRODUCT RATE LB/HR VAPOR
1	0.6506E+06	0.1164E+05					.11641+05
2	0.1248E+07	0.6623E+06					
16	0.1355E+07	0.1363E+07					

17 0.1358E+07 0.1366E+07
18 0.8042E+06 0.1369E+07 .41846+06
19 0.8610E+06 0.3973E+06
20 0.4068E+06 0.4542E+06 .40682+06

**** MOLE-X-PROFILE ****

STAGE	PROPANE	PROPENE	HYDROGEN	WATER	CO
1	0.32315E-01	0.91686	0.23392E-02	0.63258E-38	0.13996E-02
2	0.40747E-01	0.94719	0.45032E-03	0.98460E-36	0.94789E-04
16	0.38728	0.61218	0.25226E-03	0.10326E-06	0.36559E-04
17	0.43246	0.56699	0.25322E-03	0.11061E-04	0.36537E-04
18	0.47802	0.52028	0.25418E-03	0.11615E-02	0.36502E-04
19	0.48878	0.51003	0.13794E-05	0.10936E-02	0.15312E-05
20	0.51263	0.48505	0.70165E-08	0.22873E-02	0.59122E-07

**** MOLE-X-PROFILE ****

STAGE	CO2	METHANE	ETHANE	ETHENE
1	0.15704E-01	0.17390E-02	0.18338E-01	0.11304E-01
2	0.33782E-02	0.12530E-03	0.57199E-02	0.22929E-02
16	0.53641E-04	0.26264E-04	0.10124E-03	0.70823E-04
17	0.53240E-04	0.26211E-04	0.10037E-03	0.70368E-04
18	0.52779E-04	0.26143E-04	0.99395E-04	0.69849E-04
19	0.19468E-04	0.24532E-05	0.51039E-04	0.24827E-04
20	0.60651E-05	0.20763E-06	0.21934E-04	0.74708E-05

**** MOLE-Y-PROFILE ****

STAGE	PROPANE	PROPENE	HYDROGEN	WATER	CO
1	0.39011E-03	0.14647E-01	0.95581	0.31218E-44	0.16810E-01
2	0.26510E-01	0.75282	0.17570	0.51756E-38	0.42015E-02
16	0.30976	0.59224	0.94850E-01	0.85367E-09	0.16971E-02
17	0.34899	0.55305	0.94816E-01	0.93044E-07	0.16965E-02
18	0.38971	0.51233	0.94805E-01	0.99668E-05	0.16963E-02
19	0.44268	0.55625	0.51374E-03	0.11930E-04	0.73717E-04
20	0.46743	0.53239	0.26076E-05	0.25294E-04	0.28487E-05

**** MOLE-Y-PROFILE ****

STAGE	CO2	METHANE	ETHANE	ETHENE
1	0.20179E-02	0.51527E-02	0.23067E-02	0.28655E-02
2	0.13216E-01	0.23597E-02	0.15423E-01	0.97699E-02
16	0.24844E-03	0.53381E-03	0.32034E-03	0.34788E-03
17	0.24803E-03	0.53358E-03	0.31950E-03	0.34739E-03
18	0.24764E-03	0.53347E-03	0.31869E-03	0.34694E-03
19	0.10048E-03	0.52628E-04	0.17850E-03	0.13355E-03
20	0.31463E-04	0.44628E-05	0.77087E-04	0.40360E-04

**** K-VALUES ****

STAGE	PROPANE	PROPENE	HYDROGEN	WATER	CO
1	0.12072E-01	0.15975E-01	408.60	0.49350E-06	12.011
2	0.65062	0.79479	390.16	0.52566E-02	44.325
16	0.79984	0.96743	376.00	0.82669E-02	46.422
17	0.80699	0.97541	374.45	0.84117E-02	46.433
18	0.81525	0.98474	372.98	0.85808E-02	46.471
19	0.90570	1.0906	372.43	0.10910E-01	48.142
20	0.91182	1.0976	371.64	0.11059E-01	48.183

**** K-VALUES ****

STAGE	CO2	METHANE	ETHANE	ETHENE
1	0.12849	2.9629	0.12579	0.25349
2	3.9120	18.832	2.6965	4.2609
16	4.6316	20.325	3.1641	4.9119
17	4.6587	20.357	3.1833	4.9367
18	4.6920	20.406	3.2063	4.9670
19	5.1614	21.453	3.4972	5.3792

20	5.1876	21.494	3.5145	5.4023

**** MASS-X-PROFILE ****

STAGE	PROPANE	PROPENE	HYDROGEN	WATER	CO
1	0.34222E-01	0.92660	0.11325E-03	0.27369E-38	0.94153E-03
2	0.42734E-01	0.94798	0.21591E-04	0.42187E-36	0.63147E-04
16	0.39857	0.60122	0.11868E-04	0.43417E-07	0.23899E-04
17	0.44412	0.55566	0.11888E-04	0.46408E-05	0.23834E-04
18	0.49018	0.50912	0.11915E-04	0.48660E-03	0.23776E-04
19	0.50079	0.49868	0.64610E-07	0.45775E-03	0.99656E-06
20	0.52499	0.47403	0.32849E-09	0.95697E-03	0.38460E-07

**** MASS-X-PROFILE ****

STAGE	CO2	METHANE	ETHANE	ETHENE
1	0.16598E-01	0.67003E-03	0.13243E-01	0.76161E-02
2	0.35360E-02	0.47810E-04	0.40906E-02	0.15299E-02
16	0.55096E-04	0.98337E-05	0.71049E-04	0.46370E-04
17	0.54568E-04	0.97928E-05	0.70287E-04	0.45975E-04
18	0.54015E-04	0.97530E-05	0.69501E-04	0.45567E-04
19	0.19907E-04	0.91443E-06	0.35659E-04	0.16183E-04
20	0.61991E-05	0.77360E-07	0.15317E-04	0.48674E-05

**** MASS-Y-PROFILE ****

STAGE	PROPANE	PROPENE	HYDROGEN	WATER	CO
1	0.51313E-02	0.18385	0.57475	0.16776E-43	0.14045
2	0.33711E-01	0.91354	0.10214E-01	0.26888E-38	0.33938E-02
16	0.35151	0.64134	0.49205E-02	0.39577E-09	0.12233E-02
17	0.39521	0.59766	0.49086E-02	0.43047E-07	0.12204E-02
18	0.44039	0.55250	0.48977E-02	0.46014E-05	0.12176E-02
19	0.45454	0.54504	0.24115E-04	0.50047E-05	0.48080E-04
20	0.47912	0.52076	0.12219E-06	0.10592E-04	0.18548E-05

**** MASS-Y-PROFILE ****

STAGE	CO2	METHANE	ETHANE	ETHENE
1	0.26490E-01	0.24658E-01	0.20690E-01	0.23979E-01
2	0.16772E-01	0.10917E-02	0.13374E-01	0.79037E-02
16	0.28137E-03	0.22038E-03	0.24788E-03	0.25115E-03
17	0.28032E-03	0.21983E-03	0.24672E-03	0.25027E-03
18	0.27929E-03	0.21932E-03	0.24558E-03	0.24943E-03
19	0.10297E-03	0.19660E-04	0.12498E-03	0.87238E-04
20	0.32186E-04	0.16642E-05	0.53880E-04	0.26319E-04

****
***** HYDRAULIC PARAMETERS *****
****

*** DEFINITIONS ***

MARANGONI INDEX = SIGMA - SIGMATO
FLOW PARAM = (ML/MV)*SQRT(RHOV/RHOL)
QR = QV*SQRT(RHOV/(RHOL-RHOV))
F FACTOR = QV*SQRT(RHOV)
WHERE:
SIGMA IS THE SURFACE TENSION OF LIQUID FROM THE STAGE
SIGMATO IS THE SURFACE TENSION OF LIQUID TO THE STAGE
ML IS THE MASS FLOW OF LIQUID FROM THE STAGE
MV IS THE MASS FLOW OF VAPOR TO THE STAGE
RHOL IS THE MASS DENSITY OF LIQUID FROM THE STAGE
RHOV IS THE MASS DENSITY OF VAPOR TO THE STAGE

QV IS THE VOLUMETRIC FLOW RATE OF VAPOR TO THE STAGE

STAGE	TEMPERATURE F LIQUID FROM	VAPOR TO
1	-96.135	97.617
2	97.617	107.31
16	114.01	114.74
17	114.74	115.58
18	115.58	296.10
19	124.26	124.85
20	124.85	124.85

STAGE	MASS FLOW LB/HR LIQUID FROM	VAPOR TO	VOLUME FLOW CUFT/HR LIQUID FROM	VAPOR TO	MOLECULAR WEIGHT LIQUID FROM	VAPOR TO
1	0.65061E+06	0.66225E+06	16299.	0.40790E+06	41.639	34.677
2	0.12478E+07	0.12594E+07	41102.	0.72006E+06	42.046	37.993
16	0.13546E+07	0.13663E+07	46727.	0.76791E+06	42.848	38.939
17	0.13577E+07	0.13693E+07	46971.	0.76883E+06	42.939	39.022
18	0.80415E+06	0.81580E+06	27896.	0.63823E+06	43.003	36.793
19	0.86099E+06	0.45417E+06	30516.	0.23484E+06	43.039	43.021
20	0.40682E+06	0.0000	14441.	0.0000	43.059	

STAGE	DENSITY LB/CUFT LIQUID FROM	VAPOR TO	VISCOSITY CP LIQUID FROM	VAPOR TO	SURFACE TENSION DYNE/CM LIQUID FROM
1	39.918	1.6236	0.23115	0.93860E-02	19.824
2	30.358	1.7490	0.69437E-01	0.93006E-02	5.4565
16	28.990	1.7792	0.66960E-01	0.92564E-02	4.4883
17	28.905	1.7810	0.67219E-01	0.92527E-02	4.4483
18	28.827	1.2782	0.67608E-01	0.12019E-01	4.4749
19	28.215	1.9339	0.63859E-01	0.92026E-02	3.9398
20	28.171		0.64072E-01		3.9840

STAGE	MARANGONI INDEX DYNE/CM	FLOW PARAM	QR CUFT/HR	REDUCED F-FACTOR (LB-CUFT)**.5/HR
1		0.19813	83989.	0.51974E+06
2	-14.367	0.23781	0.17804E+06	0.95229E+06
16	-.39303E-01	0.24562	0.19636E+06	0.10243E+07
17	-.40036E-01	0.24612	0.19701E+06	0.10261E+07
18	0.26672E-01	0.20757	0.13748E+06	0.72157E+06
19	-.53518	0.49632	63706.	0.32659E+06
20	0.44202E-01		0.0000	0.0000

****
***** TRAY SIZING CALCULATIONS *****
****

****
*** SECTION 1 ***
****

STARTING STAGE NUMBER	2
ENDING STAGE NUMBER	19

FLOODING CALCULATION METHOD		B960

DESIGN PARAMETERS

PEAK CAPACITY FACTOR		1.00000
SYSTEM FOAMING FACTOR		1.00000
FLOODING FACTOR		0.80000
MINIMUM COLUMN DIAMETER	FT	1.00000
MINIMUM DC AREA/COLUMN AREA		0.100000

TRAY SPECIFICATIONS

TRAY TYPE		FLEXI
NUMBER OF PASSES		4
TRAY SPACING	FT	2.00000

***** SIZING RESULTS @ STAGE WITH MAXIMUM DIAMETER *****

STAGE WITH MAXIMUM DIAMETER		17
COLUMN DIAMETER	FT	23.1168
DC AREA/COLUMN AREA		0.10000
SIDE DOWNCOMER VELOCITY	FT/SEC	0.31087
FLOW PATH LENGTH	FT	4.33799
SIDE DOWNCOMER WIDTH	FT	1.40621
SIDE WEIR LENGTH	FT	11.0507
CENTER DOWNCOMER WIDTH	FT	0.90803
CENTER WEIR LENGTH	FT	23.0990
OFF-CENTER DOWNCOMER WIDTH	FT	1.02221
OFF-CENTER SHORT WEIR LENGTH	FT	19.9792
OFF-CENTER LONG WEIR LENGTH	FT	21.0365
TRAY CENTER TO OCDC CENTER	FT	5.30311

**** SIZING PROFILES ****

STAGE	DIAMETER	TOTAL AREA	ACTIVE AREA PER PANEL	SIDE DC AREA PER PANEL
	FT	SQFT	SQFT	SQFT
2	21.179	352.30	281.84	8.8075
3	22.329	391.58	313.26	9.7895
4	22.456	396.06	316.85	9.9014
5	22.492	397.33	317.87	9.9333
6	22.520	398.30	318.64	9.9574
7	22.548	399.32	319.46	9.9830
8	22.581	400.48	320.38	10.012
9	22.619	401.81	321.45	10.045
10	22.661	403.33	322.67	10.083
11	22.710	405.06	324.05	10.127
12	22.764	407.01	325.61	10.175
13	22.825	409.18	327.35	10.230
14	22.892	411.57	329.26	10.289
15	22.964	414.17	331.34	10.354
16	23.041	416.95	333.56	10.424
17	23.117	419.71	335.77	10.493
18	16.837	222.66	178.01	5.5806
19	13.682	147.03	96.961	6.2586

BLOCK: DC301 MODEL: RADFRAC

INLETS	- S301	STAGE	45
OUTLETS	- S303	STAGE	1
	S302	STAGE	90

PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS

*** MASS AND ENERGY BALANCE ***

	IN	OUT	RELATIVE DIFF.
TOTAL BALANCE			
MOLE(LBMOL/HR)	9447.99	9447.99	0.385053E-15
MASS(LB/HR)	406818.	406818.	0.429242E-15
ENTHALPY(BTU/HR)	-0.221838E+09	-0.228337E+09	0.284636E-01

*** CO2 EQUIVALENT SUMMARY ***

FEED STREAMS CO2E	3.30868	LB/HR
PRODUCT STREAMS CO2E	3.30868	LB/HR
NET STREAMS CO2E PRODUCTION	0.00000	LB/HR
UTILITIES CO2E PRODUCTION	0.00000	LB/HR
TOTAL CO2E PRODUCTION	0.00000	LB/HR

****
**** INPUT DATA ****
****

**** INPUT PARAMETERS ****

NUMBER OF STAGES	90
ALGORITHM OPTION	STANDARD
ABSORBER OPTION	NO
INITIALIZATION OPTION	STANDARD
HYDRAULIC PARAMETER CALCULATIONS	NO
INSIDE LOOP CONVERGENCE METHOD	BROYDEN
DESIGN SPECIFICATION METHOD	NESTED
MAXIMUM NO. OF OUTSIDE LOOP ITERATIONS	25
MAXIMUM NO. OF INSIDE LOOP ITERATIONS	10
MAXIMUM NUMBER OF FLASH ITERATIONS	30
FLASH TOLERANCE	0.000100000
OUTSIDE LOOP CONVERGENCE TOLERANCE	0.000100000

**** COL-SPECS ****

MOLAR VAPOR DIST / TOTAL DIST		0.0
MOLAR REFLUX RATIO		5.00000
MOLAR DISTILLATE RATE	LBMOL/HR	6,613.87

**** PROFILES ****

P-SPEC	STAGE 1	PRES, PSIA	225.000

****
**** RESULTS ****
****

*** COMPONENT SPLIT FRACTIONS ***

	OUTLET STREAMS	
	S303	S302
COMPONENT:		
PROPANE	.42156	.57844
PROPENE	.99761	.23900E-02
HYDROGEN	1.0000	0.0000
WATER	0.0000	1.0000
CO	1.0000	0.0000

CO2	1.0000	0.0000
METHANE	1.0000	0.0000
ETHANE	1.0000	0.0000
ETHENE	1.0000	0.0000

*** SUMMARY OF KEY RESULTS ***

TOP STAGE TEMPERATURE	F	102.975
BOTTOM STAGE TEMPERATURE	F	121.194
TOP STAGE LIQUID FLOW	LBMOL/HR	33,069.3
BOTTOM STAGE LIQUID FLOW	LBMOL/HR	2,834.12
TOP STAGE VAPOR FLOW	LBMOL/HR	0.0
BOILUP VAPOR FLOW	LBMOL/HR	40,342.4
MOLAR REFLUX RATIO		5.00000
MOLAR BOILUP RATIO		14.2346
CONDENSER DUTY (W/O SUBCOOL)	BTU/HR	-0.226900+09
REBOILER DUTY	BTU/HR	0.220401+09

**** MAXIMUM FINAL RELATIVE ERRORS ****

DEW POINT	0.28803E-10	STAGE= 90	
BUBBLE POINT	0.11372E-10	STAGE= 52	
COMPONENT MASS BALANCE	0.44259E-08	STAGE= 45	COMP=WATER
ENERGY BALANCE	0.18842E-08	STAGE= 1	

**** PROFILES ****

NOTE REPORTED VALUES FOR STAGE LIQUID AND VAPOR RATES ARE THE FLOWS FROM THE STAGE INCLUDING ANY SIDE PRODUCT.

STAGE	TEMPERATURE F	PRESSURE PSIA	ENTHALPY BTU/LBMOL LIQUID	ENTHALPY BTU/LBMOL VAPOR	HEAT DUTY BTU/HR
1	102.97	225.00	-13106.	-5318.9	-.22690+09
2	107.10	235.00	-15240.	-7388.4	
43	112.36	239.51	-28093.	-20098.	
44	112.40	239.62	-28093.	-20099.	
45	112.51	239.73	-28235.	-20198.	
46	112.81	239.84	-29154.	-21151.	
87	120.46	244.35	-49364.	-43810.	
88	120.51	244.46	-49411.	-43867.	
89	120.57	244.57	-49458.	-43918.	
90	121.19	244.68	-49982.	-43958.	.22040+09

STAGE	FLOW RATE LBMOL/HR LIQUID	FLOW RATE LBMOL/HR VAPOR	FEED RATE LBMOL/HR LIQUID	FEED RATE LBMOL/HR VAPOR	FEED RATE LBMOL/HR MIXED	PRODUCT RATE LBMOL/HR LIQUID	PRODUCT RATE LBMOL/HR VAPOR
1	0.3968E+05	0.000				6613.8678	
2	0.3390E+05	0.3968E+05					
43	0.3417E+05	0.4078E+05					
44	0.3416E+05	0.4078E+05		979.4859			
45	0.4265E+05	0.3980E+05	8468.5026				
46	0.4266E+05	0.3981E+05					
87	0.4325E+05	0.4040E+05					
88	0.4325E+05	0.4041E+05					
89	0.4318E+05	0.4042E+05					
90	2834.	0.4034E+05				2834.1207	

**** MASS FLOW PROFILES ****

STAGE	FLOW RATE LB/HR		FEED RATE LB/HR			PRODUCT RATE LB/HR	
	LIQUID	VAPOR	LIQUID	VAPOR	MIXED	LIQUID	VAPOR
1	0.1695E+07	0.000				.28243+06	
2	0.1450E+07	0.1695E+07					
43	0.1479E+07	0.1761E+07					
44	0.1479E+07	0.1761E+07		.42146+05			
45	0.1845E+07	0.1719E+07	.36467+06				
46	0.1847E+07	0.1721E+07					
87	0.1906E+07	0.1781E+07					
88	0.1906E+07	0.1781E+07					
89	0.1903E+07	0.1782E+07					
90	0.1244E+06	0.1778E+07				.12439+06	

**** MOLE-X-PROFILE ****

STAGE	PROPANE	PROPENE	HYDROGEN	WATER	CO
1	0.30871	0.69124	0.10023E-07	0.77919E-90	0.84457E-07
2	0.35137	0.64862	0.22189E-10	0.95786E-88	0.15619E-08
43	0.59365	0.40635	0.37494E-11	0.66812E-07	0.25981E-09
44	0.59367	0.40632	0.37507E-11	0.61158E-05	0.25985E-09
45	0.59521	0.40428	0.81872E-13	0.51113E-03	0.40601E-10
46	0.61247	0.38702	0.20244E-15	0.51097E-03	0.81224E-12
87	0.99316	0.63397E-02	0.93843-122	0.50489E-03	0.19630E-81
88	0.99406	0.54302E-02	0.24363-124	0.50558E-03	0.39517E-83
89	0.99480	0.46178E-02	0.63280-127	0.57999E-03	0.79566E-85
90	0.98851	0.38646E-02	0.16412-129	0.76250E-02	0.15949E-86

**** MOLE-X-PROFILE ****

STAGE	CO2	METHANE	ETHANE	ETHENE
1	0.86640E-05	0.29661E-06	0.31333E-04	0.10672E-04
2	0.16874E-05	0.12681E-07	0.88752E-05	0.19354E-05
43	0.31540E-06	0.21326E-08	0.18146E-05	0.36008E-06
44	0.31538E-06	0.21328E-08	0.18145E-05	0.36008E-06
45	0.22016E-06	0.64755E-09	0.14369E-05	0.24520E-06
46	0.44419E-07	0.29633E-10	0.42179E-06	0.46418E-07
87	0.31783E-36	0.26419E-65	0.14196E-28	0.31627E-37
88	0.60907E-37	0.11996E-66	0.39553E-29	0.57437E-38
89	0.11648E-37	0.54469E-68	0.10979E-29	0.10412E-38
90	0.21892E-38	0.24558E-69	0.29893E-30	0.18578E-39

**** MOLE-Y-PROFILE ****

STAGE	PROPANE	PROPENE	HYDROGEN	WATER	CO
1	0.26866	0.73111	0.47458E-05	0.58782E-92	0.46948E-05
2	0.30871	0.69124	0.10023E-07	0.77919E-90	0.84457E-07
43	0.54741	0.45258	0.16289E-08	0.61113E-09	0.13917E-07
44	0.54744	0.45255	0.16287E-08	0.55976E-07	0.13915E-07
45	0.54933	0.45066	0.35536E-10	0.46889E-05	0.21741E-08
46	0.56721	0.43279	0.87701E-13	0.47214E-05	0.43491E-10
87	0.99239	0.76029E-02	0.38702-119	0.55411E-05	0.10438E-79
88	0.99348	0.65133E-02	0.10042-121	0.55538E-05	0.21007E-81
89	0.99445	0.55400E-02	0.26071-124	0.63779E-05	0.42287E-83
90	0.99524	0.46707E-02	0.67714-127	0.85071E-04	0.85044E-85

**** MOLE-Y-PROFILE ****

STAGE	CO2	METHANE	ETHANE	ETHENE
1	0.44360E-04	0.70787E-05	0.11069E-03	0.59116E-04
2	0.86640E-05	0.29661E-06	0.31333E-04	0.10672E-04
43	0.16696E-05	0.49897E-07	0.66025E-05	0.20327E-05
44	0.16694E-05	0.49892E-07	0.66019E-05	0.20325E-05
45	0.11663E-05	0.15150E-07	0.52312E-05	0.13848E-05
46	0.23584E-06	0.69364E-09	0.15391E-05	0.26266E-06
87	0.17738E-35	0.62277E-64	0.54448E-28	0.18629E-36
88	0.33996E-36	0.28272E-65	0.15171E-28	0.33832E-37

89	0.65025E-37	0.12835E-66	0.42117E-29	0.61334E-38
90	0.12313E-37	0.58123E-68	0.11541E-29	0.11013E-38

**** K-VALUES ****

STAGE	PROPANE	PROPENE	HYDROGEN	WATER	CO
1	0.87027	1.0577	473.48	0.75440E-02	55.588
2	0.87860	1.0657	451.72	0.81347E-02	54.075
43	0.92211	1.1138	434.44	0.91470E-02	53.566
44	0.92213	1.1138	434.25	0.91527E-02	53.550
45	0.92292	1.1147	434.03	0.91737E-02	53.549
46	0.92610	1.1182	433.22	0.92401E-02	53.544
87	0.99923	1.1993	412.41	0.10975E-01	53.174
88	0.99941	1.1994	412.20	0.10985E-01	53.159
89	0.99965	1.1997	412.00	0.10997E-01	53.146
90	1.0068	1.2086	412.58	0.11157E-01	53.323

**** K-VALUES ****

STAGE	CO2	METHANE	ETHANE	ETHENE
1	5.1200	23.865	3.5326	5.5393
2	5.1345	23.390	3.5304	5.5141
43	5.2935	23.398	3.6386	5.6452
44	5.2934	23.392	3.6384	5.6447
45	5.2973	23.396	3.6407	5.6478
46	5.3093	23.408	3.6491	5.6585
87	5.5811	23.572	3.8354	5.8903
88	5.5816	23.568	3.8356	5.8903
89	5.5824	23.565	3.8360	5.8907
90	5.6243	23.668	3.8606	5.9281

**** MASS-X-PROFILE ****

STAGE	PROPANE	PROPENE	HYDROGEN	WATER	CO
1	0.31879	0.68117	0.47317E-09	0.32872E-90	0.55399E-07
2	0.36211	0.63788	0.10454E-11	0.40328E-88	0.10224E-08
43	0.60489	0.39511	0.17465E-12	0.27812E-07	0.16815E-09
44	0.60491	0.39509	0.17471E-12	0.25459E-05	0.16819E-09
45	0.60660	0.39318	0.38145E-14	0.21282E-03	0.26283E-10
46	0.62369	0.37610	0.94240E-17	0.21258E-03	0.52540E-12
87	0.99374	0.60534E-02	0.42926-123	0.20639E-03	0.12477E-81
88	0.99461	0.51848E-02	0.11144-125	0.20666E-03	0.25115E-83
89	0.99535	0.44091E-02	0.28945-128	0.23708E-03	0.50569E-85
90	0.99316	0.37053E-02	0.75383-131	0.31298E-02	0.10178E-86

**** MASS-X-PROFILE ****

STAGE	CO2	METHANE	ETHANE	ETHENE
1	0.89293E-05	0.11143E-06	0.22064E-04	0.70112E-05
2	0.17356E-05	0.47546E-08	0.62370E-05	0.12689E-05
43	0.32074E-06	0.79053E-09	0.12608E-05	0.23341E-06
44	0.32071E-06	0.79063E-09	0.12608E-05	0.23341E-06
45	0.22394E-06	0.24009E-09	0.99856E-06	0.15898E-06
46	0.45144E-07	0.10978E-10	0.29289E-06	0.30072E-07
87	0.31739E-36	0.96172E-66	0.96862E-29	0.20133E-37
88	0.60821E-37	0.43666E-67	0.26986E-29	0.36561E-38
89	0.11632E-37	0.19827E-68	0.74911E-30	0.66277E-39
90	0.21951E-38	0.89764E-70	0.20481E-30	0.11875E-39

**** MASS-Y-PROFILE ****

STAGE	PROPANE	PROPENE	HYDROGEN	WATER	CO
1	0.27797	0.72186	0.22447E-06	0.24847E-92	0.30855E-05
2	0.31879	0.68117	0.47317E-09	0.32872E-90	0.55399E-07
43	0.55898	0.44101	0.76040E-10	0.25495E-09	0.90268E-08
44	0.55901	0.44099	0.76031E-10	0.23352E-07	0.90258E-08
45	0.56089	0.43910	0.16587E-11	0.19559E-05	0.14101E-08
46	0.57866	0.42134	0.40902E-14	0.19678E-05	0.28183E-10

87	0.99274	0.72579E-02	0.17699-120	0.22646E-05	0.66328E-80
88	0.99378	0.62174E-02	0.45923-123	0.22696E-05	0.13348E-81
89	0.99471	0.52881E-02	0.11922-125	0.26063E-05	0.26868E-83
90	0.99551	0.44584E-02	0.30964-128	0.34764E-04	0.54035E-85

**** MASS-Y-PROFILE ****

STAGE	CO2	METHANE	ETHANE	ETHENE
1	0.45807E-04	0.26645E-05	0.78093E-04	0.38912E-04
2	0.89293E-05	0.11143E-06	0.22064E-04	0.70112E-05
43	0.17015E-05	0.18537E-07	0.45974E-05	0.13205E-05
44	0.17013E-05	0.18535E-07	0.45970E-05	0.13204E-05
45	0.11885E-05	0.56277E-08	0.36422E-05	0.89956E-06
46	0.24012E-06	0.25745E-09	0.10707E-05	0.17047E-06
87	0.17710E-35	0.22665E-64	0.37141E-28	0.11856E-36
88	0.33939E-36	0.10289E-65	0.10348E-28	0.21530E-37
89	0.64913E-37	0.46708E-67	0.28727E-29	0.39030E-38
90	0.12292E-37	0.21151E-68	0.78718E-30	0.70082E-39

****
***** HYDRAULIC PARAMETERS *****
****

*** DEFINITIONS ***

MARANGONI INDEX = SIGMA - SIGMATO
FLOW PARAM = (ML/MV)*SQRT(RHOV/RHOL)
QR = QV*SQRT(RHOV/(RHOL-RHOV))
F FACTOR = QV*SQRT(RHOV)
WHERE:
SIGMA IS THE SURFACE TENSION OF LIQUID FROM THE STAGE
SIGMATO IS THE SURFACE TENSION OF LIQUID TO THE STAGE
ML IS THE MASS FLOW OF LIQUID FROM THE STAGE
MV IS THE MASS FLOW OF VAPOR TO THE STAGE
RHOL IS THE MASS DENSITY OF LIQUID FROM THE STAGE
RHOV IS THE MASS DENSITY OF VAPOR TO THE STAGE
QV IS THE VOLUMETRIC FLOW RATE OF VAPOR TO THE STAGE

TEMPERATURE
F

STAGE	LIQUID FROM	VAPOR TO
1	102.97	107.10
2	107.10	107.71
43	112.36	112.40
44	112.40	112.48
45	112.51	112.81
46	112.81	113.13
87	120.46	120.51
88	120.51	120.57
89	120.57	121.19
90	121.19	121.19

	MASS FLOW LB/HR		VOLUME FLOW CUFT/HR		MOLECULAR WEIGHT	
STAGE	LIQUID FROM	VAPOR TO	LIQUID FROM	VAPOR TO	LIQUID FROM	VAPOR TO
1	0.16946E+07	0.16946E+07	56856.	0.10271E+07	42.702	42.702
2	0.14504E+07	0.17329E+07	49173.	0.10491E+07	42.789	42.775
43	0.14786E+07	0.17611E+07	51073.	0.10448E+07	43.277	43.184

44	0.14786E+07	0.17610E+07	51075.	0.10449E+07	43.277	43.184
45	0.18452E+07	0.17209E+07	63747.	0.10198E+07	43.268	43.224
46	0.18474E+07	0.17231E+07	63897.	0.10203E+07	43.303	43.261
87	0.19059E+07	0.17815E+07	67762.	0.10293E+07	44.071	44.083
88	0.19063E+07	0.17819E+07	67786.	0.10291E+07	44.072	44.085
89	0.19029E+07	0.17785E+07	67673.	0.10278E+07	44.072	44.085
90	0.12439E+06	0.0000	4416.6	0.0000	43.890	

	DENSITY LB/CUFT		VISCOSITY CP		SURFACE TENSION DYNE/CM
STAGE	LIQUID FROM	VAPOR TO	LIQUID FROM	VAPOR TO	LIQUID FROM
1	29.804	1.6499	0.71376E-01	0.89929E-02	5.1864
2	29.496	1.6517	0.69952E-01	0.89895E-02	4.9245
43	28.951	1.6856	0.70752E-01	0.89870E-02	4.6151
44	28.949	1.6853	0.70734E-01	0.89882E-02	4.6131
45	28.947	1.6874	0.70785E-01	0.89860E-02	4.6391
46	28.913	1.6887	0.70876E-01	0.89839E-02	4.6218
87	28.126	1.7309	0.72486E-01	0.89411E-02	4.2016
88	28.122	1.7315	0.72473E-01	0.89415E-02	4.1986
89	28.119	1.7304	0.72467E-01	0.89501E-02	4.2001
90	28.164		0.73213E-01		4.6125

STAGE	MARANGONI INDEX DYNE/CM	FLOW PARAM	QR CUFT/HR	REDUCED F-FACTOR (LB-CUFT)**.5/HR
1		0.23528	0.24863E+06	0.13193E+07
2	-.26191	0.19807	0.25552E+06	0.13483E+07
43	-.23410E-02	0.20259	0.25977E+06	0.13564E+07
44	-.19832E-02	0.20259	0.25979E+06	0.13565E+07
45	-.16389E-01	0.25890	0.25373E+06	0.13247E+07
46	-.17354E-01	0.25912	0.25412E+06	0.13259E+07
87	-.30775E-02	0.26539	0.26357E+06	0.13541E+07
88	-.29385E-02	0.26546	0.26360E+06	0.13541E+07
89	0.14937E-02	0.26542	0.26319E+06	0.13520E+07
90	0.41235		0.0000	0.0000

****
***** TRAY SIZING CALCULATIONS *****
****

****
*** SECTION 1 ***
****

STARTING STAGE NUMBER		2
ENDING STAGE NUMBER		89
FLOODING CALCULATION METHOD		B960
DESIGN PARAMETERS		
PEAK CAPACITY FACTOR		1.00000
SYSTEM FOAMING FACTOR		1.00000
FLOODING FACTOR		0.80000
MINIMUM COLUMN DIAMETER	FT	1.00000
MINIMUM DC AREA/COLUMN AREA		0.100000

TRAY SPECIFICATIONS

TRAY TYPE		FLEXI
NUMBER OF PASSES		4
TRAY SPACING	FT	2.00000

***** SIZING RESULTS @ STAGE WITH MAXIMUM DIAMETER *****

STAGE WITH MAXIMUM DIAMETER		88
COLUMN DIAMETER	FT	29.8775
DC AREA/COLUMN AREA		0.10000
SIDE DOWNCOMER VELOCITY	FT/SEC	0.26857
FLOW PATH LENGTH	FT	5.60666
SIDE DOWNCOMER WIDTH	FT	1.81746
SIDE WEIR LENGTH	FT	14.2826
CENTER DOWNCOMER WIDTH	FT	1.17359
CENTER WEIR LENGTH	FT	29.8544
OFF-CENTER DOWNCOMER WIDTH	FT	1.32116
OFF-CENTER SHORT WEIR LENGTH	FT	25.8222
OFF-CENTER LONG WEIR LENGTH	FT	27.1888
TRAY CENTER TO OCDC CENTER	FT	6.85403

**** SIZING PROFILES ****

STAGE	DIAMETER	TOTAL AREA	ACTIVE AREA PER PANEL	SIDE DC AREA PER PANEL
	FT	SQFT	SQFT	SQFT
2	25.358	505.02	404.02	12.625
3	25.427	507.80	406.24	12.695
4	25.489	510.26	408.21	12.756
5	25.543	512.41	409.93	12.810
6	25.589	514.29	411.43	12.857
7	25.629	515.90	412.72	12.897
8	25.664	517.28	413.82	12.932
9	25.693	518.45	414.76	12.961
10	25.717	519.45	415.56	12.986
11	25.738	520.30	416.24	13.007
12	25.756	521.02	416.81	13.025
13	25.771	521.62	417.30	13.041
14	25.784	522.14	417.71	13.054
15	25.795	522.59	418.07	13.065
16	25.804	522.97	418.37	13.074
17	25.812	523.30	418.64	13.082
18	25.820	523.58	418.87	13.090
19	25.826	523.84	419.07	13.096
20	25.831	524.06	419.25	13.101
21	25.836	524.26	419.41	13.107
22	25.841	524.44	419.55	13.111
23	25.845	524.61	419.69	13.115
24	25.849	524.76	419.81	13.119
25	25.852	524.90	419.92	13.123
26	25.855	525.04	420.03	13.126
27	25.859	525.17	420.13	13.129
28	25.862	525.29	420.23	13.132
29	25.864	525.41	420.33	13.135
30	25.867	525.52	420.42	13.138
31	25.870	525.63	420.51	13.141
32	25.873	525.74	420.59	13.144
33	25.875	525.85	420.68	13.146
34	25.878	525.95	420.76	13.149
35	25.880	526.06	420.85	13.151
36	25.883	526.16	420.93	13.154
37	25.885	526.26	421.01	13.157

38	25.888	526.36	421.09	13.159
39	25.890	526.47	421.17	13.162
40	25.893	526.57	421.25	13.164
41	25.895	526.67	421.33	13.167
42	25.898	526.77	421.41	13.169
43	25.900	526.87	421.49	13.172
44	25.901	526.91	421.53	13.173
45	28.656	644.93	515.95	16.123
46	28.702	647.01	517.61	16.175
47	28.749	649.15	519.32	16.229
48	28.798	651.35	521.08	16.284
49	28.848	653.60	522.88	16.340
50	28.898	655.87	524.70	16.397
51	28.948	658.16	526.53	16.454
52	28.999	660.46	528.37	16.512
53	29.049	662.74	530.19	16.569
54	29.098	665.00	532.00	16.625
55	29.147	667.22	533.77	16.680
56	29.194	669.38	535.51	16.735
57	29.240	671.49	537.19	16.787
58	29.284	673.52	538.81	16.838
59	29.326	675.47	540.37	16.887
60	29.367	677.33	541.87	16.933
61	29.405	679.11	543.29	16.978
62	29.442	680.79	544.63	17.020
63	29.476	682.38	545.91	17.060
64	29.508	683.88	547.10	17.097
65	29.539	685.29	548.23	17.132
66	29.567	686.60	549.28	17.165
67	29.593	687.83	550.27	17.196
68	29.618	688.98	551.18	17.224
69	29.641	690.05	552.04	17.251
70	29.663	691.05	552.84	17.276
71	29.682	691.97	553.58	17.299
72	29.701	692.83	554.27	17.321
73	29.718	693.64	554.91	17.341
74	29.734	694.38	555.51	17.360
75	29.749	695.08	556.06	17.377
76	29.763	695.73	556.58	17.393
77	29.776	696.34	557.07	17.408
78	29.788	696.91	557.53	17.423
79	29.799	697.44	557.95	17.436
80	29.810	697.94	558.35	17.449
81	29.820	698.41	558.73	17.460
82	29.830	698.86	559.09	17.472
83	29.839	699.28	559.43	17.482
84	29.847	699.68	559.75	17.492
85	29.856	700.07	560.05	17.502
86	29.863	700.43	560.35	17.511
87	29.871	700.78	560.63	17.520
88	29.877	701.10	560.88	17.527
89	29.840	699.34	559.47	17.483

BLOCK: H000 MODEL: HEATER

INLET STREAM:	1	
INLET HEAT STREAM:	S2	
OUTLET STREAM:	S110	
PROPERTY OPTION SET:	UNIQUAC	UNIQUAC / IDEAL GAS

```
 *     BLOCK IS IN MASS IMBALANCE                                              *
 *                                                                             *
 *******************************************************************************


                    ***  MASS AND ENERGY BALANCE  ***
                                 IN                OUT         RELATIVE DIFF.
 TOTAL BALANCE
    MOLE(LBMOL/HR)             35660.4           35313.9          0.971749E-02
    MASS(LB/HR   )             831549.           824709.          0.822513E-02
    ENTHALPY(BTU/HR  )      -0.199808E+10     -0.196830E+10     -0.149028E-01

                    ***  CO2 EQUIVALENT SUMMARY ***
 FEED STREAMS CO2E             12430.5       LB/HR
 PRODUCT STREAMS CO2E          12430.4       LB/HR
 NET STREAMS CO2E PRODUCTION -0.988521E-01   LB/HR
 UTILITIES CO2E PRODUCTION      0.00000      LB/HR
 TOTAL CO2E PRODUCTION       -0.988521E-01   LB/HR

                       ***  INPUT DATA  ***
 TWO    PHASE  PQ  FLASH
 SPECIFIED PRESSURE                    PSIA                      52.5000
 DUTY FROM INLET HEAT STREAM(S)        BTU/HR                     0.683458+08
 MAXIMUM NO. ITERATIONS                                          30
 CONVERGENCE TOLERANCE                                           0.000100000


                       ***  RESULTS  ***
 OUTLET TEMPERATURE    F                                         1210.7
 OUTLET PRESSURE       PSIA                                      52.500
 OUTLET VAPOR FRACTION                                           1.0000


 V-L PHASE EQUILIBRIUM :

    COMP              F(I)           X(I)           Y(I)           K(I)
    PROPANE          0.13586        0.16235E-02    0.13586        753.49
    PROPENE          0.13063        0.13127E-02    0.13063        935.38
    HYDROGEN         0.93162E-01    0.13769E-04    0.93162E-01    2627.1
    WATER            0.63439        0.99703        0.63439        623.37
    CO               0.16368E-02    0.11365E-05    0.16368E-02    1632.8
    CO2              0.33015E-02    0.11405E-04    0.33015E-02    2353.9
    METHANE          0.50684E-03    0.67055E-06    0.50684E-03    1384.3
    ETHANE           0.23281E-03    0.10860E-05    0.23281E-03    1117.3
    ETHENE           0.28100E-03    0.91769E-06    0.28100E-03    1308.7

BLOCK:  H101     MODEL: HEATER
------------------------------
 INLET STREAM:          S102
 INLET HEAT STREAMS:    S9          S16
 OUTLET STREAM:         S104
 PROPERTY OPTION SET:   UNIQUAC   UNIQUAC / IDEAL GAS

                    ***  MASS AND ENERGY BALANCE  ***
                                 IN                OUT         RELATIVE DIFF.
 TOTAL BALANCE
    MOLE(LBMOL/HR)             21396.9           21396.9          0.00000
    MASS(LB/HR   )             385471.           385471.          0.00000
    ENTHALPY(BTU/HR  )      -0.215605E+10     -0.215605E+10     0.221162E-15

                    ***  CO2 EQUIVALENT SUMMARY ***
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 FEED STREAMS CO2E             0.00000      LB/HR
 PRODUCT STREAMS CO2E          0.00000      LB/HR
 NET STREAMS CO2E PRODUCTION   0.00000      LB/HR
 UTILITIES CO2E PRODUCTION     0.00000      LB/HR
 TOTAL CO2E PRODUCTION         0.00000      LB/HR

                          ***  INPUT DATA  ***
TWO    PHASE  PQ  FLASH
SPECIFIED PRESSURE                  PSIA                    72.5189
DUTY FROM INLET HEAT STREAM(S)      BTU/HR                   0.438439+09
MAXIMUM NO. ITERATIONS                                      30
CONVERGENCE TOLERANCE                                        0.000100000


                          ***  RESULTS  ***
OUTLET TEMPERATURE    F                                     466.70
OUTLET PRESSURE       PSIA                                  72.519
OUTLET VAPOR FRACTION                                       1.0000


V-L PHASE EQUILIBRIUM :

   COMP              F(I)          X(I)          Y(I)          K(I)
   WATER             1.0000        1.0000        1.0000        6.8627

BLOCK:  H103     MODEL: HEATER
------------------------------
INLET STREAM:          S112
OUTLET STREAM:         S114
OUTLET WATER STREAM:   S1
PROPERTY OPTION SET:   UNIQUAC   UNIQUAC / IDEAL GAS
FREE WATER OPTION SET: SYSOP12   ASME STEAM TABLE
SOLUBLE WATER OPTION:  THE MAIN PROPERTY OPTION SET (UNIQUAC ).

                     ***  MASS AND ENERGY BALANCE  ***
                                IN              OUT        RELATIVE DIFF.
 TOTAL BALANCE
    MOLE(LBMOL/HR)            35313.9         35313.9         0.00000
    MASS(LB/HR   )            824709.         824709.        0.282318E-15
    ENTHALPY(BTU/HR  )      -0.238191E+10   -0.287181E+10    0.170588

                     ***  CO2 EQUIVALENT SUMMARY ***
 FEED STREAMS CO2E             12430.4      LB/HR
 PRODUCT STREAMS CO2E          12430.4      LB/HR
 NET STREAMS CO2E PRODUCTION   0.00000      LB/HR
 UTILITIES CO2E PRODUCTION     0.00000      LB/HR
 TOTAL CO2E PRODUCTION         0.00000      LB/HR

                          ***  INPUT DATA  ***
TWO    PHASE  TP  FLASH
FREE WATER CONSIDERED
SPECIFIED TEMPERATURE               F                       176.000
SPECIFIED PRESSURE                  PSIA                     34.8091
MAXIMUM NO. ITERATIONS                                      30
CONVERGENCE TOLERANCE                                        0.000100000


                          ***  RESULTS  ***
OUTLET TEMPERATURE    F                                     176.00
OUTLET PRESSURE       PSIA                                  34.809
```

HEAT DUTY	BTU/HR	-0.48990E+09
OUTLET VAPOR FRACTION		0.38573
OUTLET: 1ST LIQUID/TOTAL LIQUID		0.0000

V-L1-L2 PHASE EQUILIBRIUM :

COMP	F(I)	X1(I)	X2(I)	Y(I)	K1(I)	K2(I)
PROPANE	0.137	0.547E-01	0.00	0.356	26.4	
PROPENE	0.131	0.432E-01	0.00	0.340	32.0	
HYDROGEN	0.941E-01	0.229E-03	0.00	0.244	0.433E+04	
WATER	0.632	0.901	1.00	0.447E-01	0.201	0.447E-01
CO	0.165E-02	0.236E-04	0.00	0.429E-02	737.	0.447E-01
CO2	0.333E-02	0.305E-03	0.00	0.864E-02	115.	
METHANE	0.512E-03	0.148E-04	0.00	0.133E-02	363.	
ETHANE	0.235E-03	0.304E-04	0.00	0.609E-03	81.4	
ETHENE	0.284E-03	0.245E-04	0.00	0.736E-03	122.	

BLOCK: H301 MODEL: HEATER

INLET STREAM:	S305	
OUTLET STREAM:	S306	
PROPERTY OPTION SET:	UNIQUAC	UNIQUAC / IDEAL GAS

*** MASS AND ENERGY BALANCE ***

	IN	OUT	RELATIVE DIFF.
TOTAL BALANCE			
MOLE(LBMOL/HR)	6613.87	6613.87	0.00000
MASS(LB/HR)	282428.	282428.	0.00000
ENTHALPY(BTU/HR)	-0.848981E+08	-0.305659E+08	-0.639969

*** CO2 EQUIVALENT SUMMARY ***

FEED STREAMS CO2E	3.30868	LB/HR
PRODUCT STREAMS CO2E	3.30868	LB/HR
NET STREAMS CO2E PRODUCTION	0.00000	LB/HR
UTILITIES CO2E PRODUCTION	0.00000	LB/HR
TOTAL CO2E PRODUCTION	0.00000	LB/HR

*** INPUT DATA ***

TWO PHASE TP FLASH		
SPECIFIED TEMPERATURE	F	257.000
SPECIFIED PRESSURE	PSIA	575.000
MAXIMUM NO. ITERATIONS		30
CONVERGENCE TOLERANCE		0.000100000

*** RESULTS ***

OUTLET TEMPERATURE	F	257.00
OUTLET PRESSURE	PSIA	575.00
HEAT DUTY	BTU/HR	0.54332E+08
OUTLET VAPOR FRACTION		1.0000

V-L PHASE EQUILIBRIUM :

COMP	F(I)	X(I)	Y(I)	K(I)
PROPANE	0.30871	0.34766	0.30871	1.6679
PROPENE	0.69124	0.65232	0.69124	1.9904
HYDROGEN	0.10023E-07	0.10195E-09	0.10023E-07	184.67
CO	0.84457E-07	0.42657E-08	0.84457E-07	37.190

CO2	0.86640E-05	0.19601E-05	0.86640E-05	8.3025
METHANE	0.29661E-06	0.28084E-07	0.29661E-06	19.838
ETHANE	0.31333E-04	0.11685E-04	0.31333E-04	5.0367
ETHENE	0.10672E-04	0.28170E-05	0.10672E-04	7.1160

BLOCK: H302 MODEL: HEATER

INLET STREAM: S315
OUTLET STREAM: S316
PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS

*** MASS AND ENERGY BALANCE ***

	IN	OUT	RELATIVE DIFF.
TOTAL BALANCE			
MOLE(LBMOL/HR)	4207.62	4207.62	0.00000
MASS(LB/HR)	177102.	177102.	0.00000
ENTHALPY(BTU/HR)	0.544198E+08	0.133028E+08	0.755553

*** CO2 EQUIVALENT SUMMARY ***

FEED STREAMS CO2E	0.00000	LB/HR
PRODUCT STREAMS CO2E	0.00000	LB/HR
NET STREAMS CO2E PRODUCTION	0.00000	LB/HR
UTILITIES CO2E PRODUCTION	0.00000	LB/HR
TOTAL CO2E PRODUCTION	0.00000	LB/HR

*** INPUT DATA ***

TWO PHASE TP FLASH		
SPECIFIED TEMPERATURE	F	100.0000
SPECIFIED PRESSURE	PSIA	250.000
MAXIMUM NO. ITERATIONS		30
CONVERGENCE TOLERANCE		0.000100000

*** RESULTS ***

OUTLET TEMPERATURE	F	100.00
OUTLET PRESSURE	PSIA	250.00
HEAT DUTY	BTU/HR	-0.41117E+08
OUTLET VAPOR FRACTION		0.0000

V-L PHASE EQUILIBRIUM :

COMP	F(I)	X(I)	Y(I)	K(I)
PROPANE	0.50000E-02	0.50000E-02	0.41005E-02	0.75173
PROPENE	0.99500	0.99500	0.99590	0.91745

BLOCK: H303 MODEL: HEATER

INLET STREAM: RECY
OUTLET STREAM: S313
PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS

*** MASS AND ENERGY BALANCE ***

	IN	OUT	RELATIVE DIFF.
TOTAL BALANCE			
MOLE(LBMOL/HR)	4716.34	4716.34	0.00000
MASS(LB/HR)	206744.	206744.	0.00000
ENTHALPY(BTU/HR)	-0.205196E+09	-0.194699E+09	-0.511559E-01

*** CO2 EQUIVALENT SUMMARY ***

FEED STREAMS CO2E	2.97781	LB/HR

PRODUCT STREAMS CO2E	2.97781	LB/HR
NET STREAMS CO2E PRODUCTION	0.00000	LB/HR
UTILITIES CO2E PRODUCTION	0.00000	LB/HR
TOTAL CO2E PRODUCTION	0.00000	LB/HR

*** INPUT DATA ***

TWO PHASE TP FLASH		
SPECIFIED TEMPERATURE	F	71.6000
SPECIFIED PRESSURE	PSIA	20.0000
MAXIMUM NO. ITERATIONS		30
CONVERGENCE TOLERANCE		0.000100000

*** RESULTS ***

OUTLET TEMPERATURE	F	71.600
OUTLET PRESSURE	PSIA	20.000
HEAT DUTY	BTU/HR	0.10497E+08
OUTLET VAPOR FRACTION		1.0000

V-L PHASE EQUILIBRIUM :

COMP	F(I)	X(I)	Y(I)	K(I)
PROPANE	0.92022	0.40487	0.92022	7.3098
PROPENE	0.75590E-01	0.26301E-01	0.75590E-01	9.2431
HYDROGEN	0.12650E-07	0.66560E-11	0.12650E-07	6112.4
WATER	0.41238E-02	0.56883	0.41238E-02	0.23315E-01
CO	0.10659E-06	0.56229E-09	0.10659E-06	609.67
CO2	0.10935E-04	0.79185E-06	0.10935E-04	44.412
METHANE	0.37435E-06	0.48562E-08	0.37435E-06	247.92
ETHANE	0.39545E-04	0.39982E-05	0.39545E-04	31.809
ETHENE	0.13469E-04	0.82493E-06	0.13469E-04	52.512

BLOCK: HX101 MODEL: HEATX

HOT SIDE:

INLET STREAM:	S110	
OUTLET STREAM:	S111	
PROPERTY OPTION SET:	UNIQUAC	UNIQUAC / IDEAL GAS

COLD SIDE:

INLET STREAM:	S105	
OUTLET STREAM:	S15	
PROPERTY OPTION SET:	UNIQUAC	UNIQUAC / IDEAL GAS

****
*
* CALCULATED HOT SIDE FEED TEMPERATURE INCONSISTENT WITH INLET *
*
****

*** MASS AND ENERGY BALANCE ***

	IN	OUT	RELATIVE DIFF.
TOTAL BALANCE			
MOLE(LBMOL/HR)	66310.4	66310.4	0.00000
MASS(LB/HR)	0.163226E+07	0.163226E+07	-0.142643E-15
ENTHALPY(BTU/HR)	-0.452925E+10	-0.452925E+10	0.421118E-15

*** CO2 EQUIVALENT SUMMARY ***

FEED STREAMS CO2E	12433.3	LB/HR
PRODUCT STREAMS CO2E	12433.3	LB/HR
NET STREAMS CO2E PRODUCTION	0.00000	LB/HR
UTILITIES CO2E PRODUCTION	0.00000	LB/HR
TOTAL CO2E PRODUCTION	0.00000	LB/HR

*** INPUT DATA ***

FLASH SPECS FOR HOT SIDE:

TWO PHASE FLASH		
MAXIMUM NO. ITERATIONS		30
CONVERGENCE TOLERANCE		0.000100000

FLASH SPECS FOR COLD SIDE:

TWO PHASE FLASH		
MAXIMUM NO. ITERATIONS		30
CONVERGENCE TOLERANCE		0.000100000

FLOW DIRECTION AND SPECIFICATION:

COUNTERCURRENT HEAT EXCHANGER		
SPECIFIED COLD OUTLET TEMP		
SPECIFIED VALUE	F	1094.0000
LMTD CORRECTION FACTOR		1.00000

PRESSURE SPECIFICATION:

HOT SIDE OUTLET PRESSURE	PSIA	52.5000
COLD SIDE PRESSURE DROP	PSI	0.0000

HEAT TRANSFER COEFFICIENT SPECIFICATION:

HOT LIQUID	COLD LIQUID	BTU/HR-SQFT-R	149.6937
HOT 2-PHASE	COLD LIQUID	BTU/HR-SQFT-R	149.6937
HOT VAPOR	COLD LIQUID	BTU/HR-SQFT-R	149.6937
HOT LIQUID	COLD 2-PHASE	BTU/HR-SQFT-R	149.6937
HOT 2-PHASE	COLD 2-PHASE	BTU/HR-SQFT-R	149.6937
HOT VAPOR	COLD 2-PHASE	BTU/HR-SQFT-R	149.6937
HOT LIQUID	COLD VAPOR	BTU/HR-SQFT-R	149.6937
HOT 2-PHASE	COLD VAPOR	BTU/HR-SQFT-R	149.6937
HOT VAPOR	COLD VAPOR	BTU/HR-SQFT-R	149.6937

*** OVERALL RESULTS ***

STREAMS:

S110 ----->	HOT	-----> S111
T= 1.2107D+03		T= 4.6081D+02
P= 5.2500D+01		P= 5.2500D+01
V= 1.0000D+00		V= 1.0000D+00
S15 <-----	COLD	<----- S105
T= 1.0940D+03		T= 2.8827D+02
P= 7.2519D+01		P= 7.2519D+01
V= 1.0000D+00		V= 1.0000D+00

DUTY AND AREA:

CALCULATED HEAT DUTY	BTU/HR	395114797.8539
CALCULATED (REQUIRED) AREA	SQFT	18423.3719
ACTUAL EXCHANGER AREA	SQFT	18423.3719
PER CENT OVER-DESIGN		0.0000

HEAT TRANSFER COEFFICIENT:

AVERAGE COEFFICIENT (DIRTY)	BTU/HR-SQFT-R	149.6937
UA (DIRTY)	BTU/HR-R	2757861.9035

LOG-MEAN TEMPERATURE DIFFERENCE:

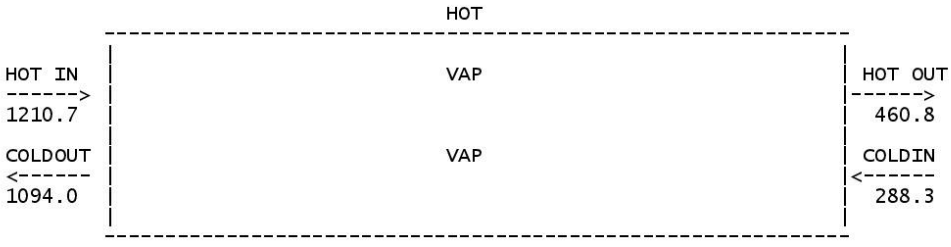
LMTD CORRECTION FACTOR		1.0000
LMTD (CORRECTED)	F	143.2685
NUMBER OF SHELLS IN SERIES		1

PRESSURE DROP:

HOTSIDE, TOTAL	PSI	0.0000
COLDSIDE, TOTAL	PSI	0.0000

*** ZONE RESULTS ***

TEMPERATURE LEAVING EACH ZONE:



ZONE HEAT TRANSFER AND AREA:

ZONE	HEAT DUTY BTU/HR	AREA SQFT	LMTD F	AVERAGE U BTU/HR-SQFT-R	UA BTU/HR-R
1	395114797.854	18423.3719	143.2685	149.6937	2757861.9035

HEATX COLD-TQCU HX101 TQCURV INLET

PRESSURE PROFILE:	CONSTANT2	
PRESSURE DROP:	0.0	PSI
PROPERTY OPTION SET:	UNIQUAC	UNIQUAC / IDEAL GAS

DUTY BTU/HR	PRES PSIA	TEMP F	VFRAC
0.0	72.5189	1094.0000	1.0000
1.8815+07	72.5189	1060.7775	1.0000
3.7630+07	72.5189	1027.2203	1.0000
5.6445+07	72.5189	993.3122	1.0000
7.5260+07	72.5189	959.0355	1.0000
9.4075+07	72.5189	924.3713	1.0000
1.1289+08	72.5189	889.2985	1.0000
1.3170+08	72.5189	853.7942	1.0000
1.5052+08	72.5189	817.8326	1.0000
1.6933+08	72.5189	781.3854	1.0000
1.8815+08	72.5189	744.4207	1.0000

2.0696+08	72.5189	706.9024	1.0000
2.2578+08	72.5189	668.7895	1.0000
2.4459+08	72.5189	630.0355	1.0000
2.6341+08	72.5189	590.5865	1.0000
2.8222+08	72.5189	550.3805	1.0000
3.0104+08	72.5189	509.3456	1.0000
3.1985+08	72.5189	467.3980	1.0000
3.3867+08	72.5189	424.4399	1.0000
3.5748+08	72.5189	380.3573	1.0000
3.7630+08	72.5189	335.0183	1.0000
3.9511+08	72.5189	288.2717	1.0000

HEATX HOT-TQCUR HX101 TQCURV INLET

PRESSURE PROFILE: CONSTANT2
PRESSURE DROP: 0.0 PSI
PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS

DUTY	PRES	TEMP	VFRAC
BTU/HR	PSIA	F	
0.0	52.5000	1211.5137	1.0000
1.8815+07	52.5000	1179.5231	1.0000
3.7630+07	52.5000	1147.2656	1.0000
5.6445+07	52.5000	1114.7297	1.0000
7.5260+07	52.5000	1081.9029	1.0000
9.4075+07	52.5000	1048.7721	1.0000
1.1289+08	52.5000	1015.3229	1.0000
1.3170+08	52.5000	981.5401	1.0000
1.5052+08	52.5000	947.4072	1.0000
1.6933+08	52.5000	912.9065	1.0000
1.8815+08	52.5000	878.0186	1.0000
2.0696+08	52.5000	842.7224	1.0000
2.2578+08	52.5000	806.9949	1.0000
2.4459+08	52.5000	770.8110	1.0000
2.6341+08	52.5000	734.1428	1.0000
2.8222+08	52.5000	696.9594	1.0000
3.0104+08	52.5000	659.2267	1.0000
3.1985+08	52.5000	620.9064	1.0000
3.3867+08	52.5000	581.9558	1.0000
3.5748+08	52.5000	542.3267	1.0000
3.7630+08	52.5000	501.9647	1.0000
3.9511+08	52.5000	460.8082	1.0000

BLOCK: HX301 MODEL: HEATX

HOT SIDE:

INLET STREAM: S309
OUTLET STREAM: S315

```
PROPERTY OPTION SET:   UNIQUAC   UNIQUAC / IDEAL GAS
COLD SIDE:
----------
INLET STREAM:             S304
OUTLET STREAM:            S305
PROPERTY OPTION SET:   UNIQUAC   UNIQUAC / IDEAL GAS

                    ***  MASS AND ENERGY BALANCE  ***
                                 IN              OUT        RELATIVE DIFF.
 TOTAL BALANCE
    MOLE(LBMOL/HR)            10821.5         10821.5          0.00000
    MASS(LB/HR   )            459530.         459530.          0.00000
    ENTHALPY(BTU/HR  )     -0.304783E+08   -0.304783E+08    0.733366E-15

                    ***  CO2 EQUIVALENT SUMMARY ***
 FEED STREAMS CO2E             3.30868      LB/HR
 PRODUCT STREAMS CO2E          3.30868      LB/HR
 NET STREAMS CO2E PRODUCTION   0.00000      LB/HR
 UTILITIES CO2E PRODUCTION     0.00000      LB/HR
 TOTAL CO2E PRODUCTION         0.00000      LB/HR

                       ***  INPUT DATA  ***

FLASH SPECS FOR HOT SIDE:
TWO    PHASE      FLASH
MAXIMUM NO. ITERATIONS                                    30
CONVERGENCE TOLERANCE                                      0.000100000

FLASH SPECS FOR COLD SIDE:
TWO    PHASE      FLASH
MAXIMUM NO. ITERATIONS                                    30
CONVERGENCE TOLERANCE                                      0.000100000

FLOW DIRECTION AND SPECIFICATION:
  COUNTERCURRENT   HEAT EXCHANGER
  SPECIFIED EXCHANGER DUTY
  SPECIFIED VALUE               BTU/HR             1000000.0000
  LMTD CORRECTION FACTOR                                1.00000

PRESSURE SPECIFICATION:
  HOT  SIDE PRESSURE DROP       PSI                     0.0000
  COLD SIDE PRESSURE DROP       PSI                     0.0000

HEAT TRANSFER COEFFICIENT SPECIFICATION:
  HOT LIQUID    COLD LIQUID     BTU/HR-SQFT-R         149.6937
  HOT 2-PHASE   COLD LIQUID     BTU/HR-SQFT-R         149.6937
  HOT VAPOR     COLD LIQUID     BTU/HR-SQFT-R         149.6937
  HOT LIQUID    COLD 2-PHASE    BTU/HR-SQFT-R         149.6937
  HOT 2-PHASE   COLD 2-PHASE    BTU/HR-SQFT-R         149.6937
  HOT VAPOR     COLD 2-PHASE    BTU/HR-SQFT-R         149.6937
  HOT LIQUID    COLD VAPOR      BTU/HR-SQFT-R         149.6937
  HOT 2-PHASE   COLD VAPOR      BTU/HR-SQFT-R         149.6937
  HOT VAPOR     COLD VAPOR      BTU/HR-SQFT-R         149.6937

                       ***  OVERALL RESULTS  ***

STREAMS:
                ------------------------------------
                |                                   |
S309      ----->|               HOT                 |-----> S315
T=  3.3827D+02  |                                   |       T=  3.2672D+02
P=  2.5000D+02  |                                   |       P=  2.5000D+02
V=  1.0000D+00  |                                   |       V=  1.0000D+00
```

```
                  |                                    |
S305      <-------|                COLD                |<------- S304
T=  1.0968D+02    |                                    |         T=  1.0595D+02
P=  5.7500D+02    |                                    |         P=  5.7500D+02
V=  0.0000D+00    |                                    |         V=  0.0000D+00
                  --------------------------------------
```

DUTY AND AREA:

CALCULATED HEAT DUTY	BTU/HR	1000000.0000
CALCULATED (REQUIRED) AREA	SQFT	29.7354
ACTUAL EXCHANGER AREA	SQFT	29.7354
PER CENT OVER-DESIGN		0.0000

HEAT TRANSFER COEFFICIENT:

AVERAGE COEFFICIENT (DIRTY)	BTU/HR-SQFT-R	149.6937
UA (DIRTY)	BTU/HR-R	4451.1936

LOG-MEAN TEMPERATURE DIFFERENCE:

LMTD CORRECTION FACTOR		1.0000
LMTD (CORRECTED)	F	224.6588
NUMBER OF SHELLS IN SERIES		1

PRESSURE DROP:

HOTSIDE, TOTAL	PSI	0.0000
COLDSIDE, TOTAL	PSI	0.0000

*** ZONE RESULTS ***

TEMPERATURE LEAVING EACH ZONE:

```
                                HOT
        ------------------------------------------------------------
        |                                                          |
HOT IN  |                          VAP                             | HOT OUT
------> |                                                          |------>
 338.3  |                                                          |  326.7
        |                                                          |
COLDOUT |                          LIQ                             | COLDIN
<------ |                                                          |<------
 109.7  |                                                          |  105.9
        |                                                          |
        ------------------------------------------------------------
                                COLD
```

ZONE HEAT TRANSFER AND AREA:

ZONE	HEAT DUTY BTU/HR	AREA SQFT	LMTD F	AVERAGE U BTU/HR-SQFT-R	UA BTU/HR-R
1	1000000.000	29.7354	224.6588	149.6937	4451.1936

HEATX COLD-TQCU HX301 TQCURV INLET

PRESSURE PROFILE:	CONSTANT2	
PRESSURE DROP:	0.0	PSI
PROPERTY OPTION SET:	UNIQUAC	UNIQUAC / IDEAL GAS

DUTY	PRES	TEMP	VFRAC
BTU/HR	PSIA	F	

0.0	575.0000	109.6769	0.0
4.7619+04	575.0000	109.5008	0.0
9.5238+04	575.0000	109.3245	0.0
1.4286+05	575.0000	109.1480	0.0
1.9048+05	575.0000	108.9714	0.0
2.3810+05	575.0000	108.7947	0.0
2.8571+05	575.0000	108.6178	0.0
3.3333+05	575.0000	108.4408	0.0
3.8095+05	575.0000	108.2636	0.0
4.2857+05	575.0000	108.0862	0.0
4.7619+05	575.0000	107.9087	0.0
5.2381+05	575.0000	107.7311	0.0
5.7143+05	575.0000	107.5533	0.0
6.1905+05	575.0000	107.3754	0.0
6.6667+05	575.0000	107.1973	0.0
7.1429+05	575.0000	107.0190	0.0
7.6190+05	575.0000	106.8406	0.0
8.0952+05	575.0000	106.6621	0.0
8.5714+05	575.0000	106.4834	0.0
9.0476+05	575.0000	106.3046	0.0
9.5238+05	575.0000	106.1256	0.0
1.0000+06	575.0000	105.9464	0.0

HEATX HOT-TQCUR HX301 TQCURV INLET

PRESSURE PROFILE: CONSTANT2
PRESSURE DROP: 0.0 PSI
PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS

DUTY	PRES	TEMP	VFRAC
BTU/HR	PSIA	F	
0.0	250.0000	338.2659	1.0000
4.7619+04	250.0000	337.7189	1.0000
9.5238+04	250.0000	337.1715	1.0000
1.4286+05	250.0000	336.6239	1.0000
1.9048+05	250.0000	336.0761	1.0000
2.3810+05	250.0000	335.5279	1.0000
2.8571+05	250.0000	334.9795	1.0000
3.3333+05	250.0000	334.4308	1.0000
3.8095+05	250.0000	333.8818	1.0000
4.2857+05	250.0000	333.3326	1.0000
4.7619+05	250.0000	332.7831	1.0000
5.2381+05	250.0000	332.2333	1.0000
5.7143+05	250.0000	331.6833	1.0000
6.1905+05	250.0000	331.1330	1.0000
6.6667+05	250.0000	330.5824	1.0000
7.1429+05	250.0000	330.0315	1.0000
7.6190+05	250.0000	329.4803	1.0000

```
!  8.0952+05 !   250.0000 !   328.9289 !     1.0000 !
!  8.5714+05 !   250.0000 !   328.3772 !     1.0000 !
!  9.0476+05 !   250.0000 !   327.8252 !     1.0000 !
!-----------+-----------+-----------+------------!
!  9.5238+05 !   250.0000 !   327.2730 !     1.0000 !
!  1.0000+06 !   250.0000 !   326.7204 !     1.0000 !
-------------------------------------------------

BLOCK:  M301     MODEL: SEP
---------------------------
  INLET STREAM:          S306
  OUTLET STREAMS:        S307        S310
  PROPERTY OPTION SET:   UNIQUAC   UNIQUAC / IDEAL GAS

                     ***  MASS AND ENERGY BALANCE  ***
                                  IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(LBMOL/HR)            6613.87         6613.87         0.00000
      MASS(LB/HR   )            282428.         282428.        -0.206097E-15
      ENTHALPY(BTU/HR  )      -0.305659E+08   -0.305659E+08    0.975018E-15

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E             3.30868      LB/HR
   PRODUCT STREAMS CO2E          3.30868      LB/HR
   NET STREAMS CO2E PRODUCTION   0.00000      LB/HR
   UTILITIES CO2E PRODUCTION     0.00000      LB/HR
   TOTAL CO2E PRODUCTION         0.00000      LB/HR


                          ***  INPUT DATA  ***

  FLASH SPECS FOR STREAM S307
  TWO    PHASE  TP  FLASH
  PRESSURE DROP         PSI                                    0.0
  MAXIMUM NO. ITERATIONS                                      30
  CONVERGENCE TOLERANCE                                       0.000100000

  FLASH SPECS FOR STREAM S310
  TWO    PHASE  TP  FLASH
  PRESSURE DROP         PSI                                    0.0
  MAXIMUM NO. ITERATIONS                                      30
  CONVERGENCE TOLERANCE                                       0.000100000

  MOLE-FLOW (LBMOL/HR)
    SUBSTREAM= MIXED
      STREAM= S307      CPT= PROPANE   FLOW=             21.0380
                             PROPENE                  4,186.58


                           ***  RESULTS  ***

  HEAT DUTY             BTU/HR                              -0.31778E-07

 COMPONENT = PROPANE
   STREAM     SUBSTREAM    SPLIT FRACTION
   S307       MIXED                0.010304
   S310       MIXED                0.98970

 COMPONENT = PROPENE
   STREAM     SUBSTREAM    SPLIT FRACTION
   S307       MIXED                0.91575
   S310       MIXED                0.084250
```

```
 COMPONENT = HYDROGEN
   STREAM     SUBSTREAM    SPLIT FRACTION
   S310       MIXED                1.00000

 COMPONENT = CO
   STREAM     SUBSTREAM    SPLIT FRACTION
   S310       MIXED                1.00000

 COMPONENT = CO2
   STREAM     SUBSTREAM    SPLIT FRACTION
   S310       MIXED                1.00000

 COMPONENT = METHANE
   STREAM     SUBSTREAM    SPLIT FRACTION
   S310       MIXED                1.00000

 COMPONENT = ETHANE
   STREAM     SUBSTREAM    SPLIT FRACTION
   S310       MIXED                1.00000

 COMPONENT = ETHENE
   STREAM     SUBSTREAM    SPLIT FRACTION
   S310       MIXED                1.00000

BLOCK:  MEA201   MODEL: SEP
------------------------------
  INLET STREAM:          S203
  OUTLET STREAMS:        S204        S205
  PROPERTY OPTION SET:   UNIQUAC   UNIQUAC / IDEAL GAS

                     ***  MASS AND ENERGY BALANCE  ***
                                  IN               OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(LBMOL/HR)            13043.1          13043.1       -0.278920E-15
      MASS(LB/HR   )            423494.          423494.        0.137446E-15
      ENTHALPY(BTU/HR  )     -0.185147E+09    -0.185147E+09     0.160966E-15

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E             12357.9      LB/HR
   PRODUCT STREAMS CO2E          12357.9      LB/HR
   NET STREAMS CO2E PRODUCTION   0.00000      LB/HR
   UTILITIES CO2E PRODUCTION     0.00000      LB/HR
   TOTAL CO2E PRODUCTION         0.00000      LB/HR


                        ***  INPUT DATA  ***

  FLASH SPECS FOR STREAM S204
  TWO    PHASE  TP  FLASH
  PRESSURE DROP         PSI                                  0.0
  MAXIMUM NO. ITERATIONS                                    30
  CONVERGENCE TOLERANCE                                      0.000100000

  FLASH SPECS FOR STREAM S205
  TWO    PHASE  TP  FLASH
  PRESSURE DROP         PSI                                  0.0
  MAXIMUM NO. ITERATIONS                                    30
  CONVERGENCE TOLERANCE                                      0.000100000

  FRACTION OF FEED
    SUBSTREAM= MIXED
      STREAM= S204      CPT= PROPANE   FRACTION=          0.0
                             PROPENE                     0.0
```

HYDROGEN	0.00100000
OXYGEN	0.0
WATER	0.29000
CO	0.0
CO2	0.94000
METHANE	0.0
ETHANE	0.0
ETHENE	0.0

*** RESULTS ***

HEAT DUTY BTU/HR -0.25422E-07

COMPONENT = PROPANE

STREAM	SUBSTREAM	SPLIT FRACTION
S205	MIXED	1.00000

COMPONENT = PROPENE

STREAM	SUBSTREAM	SPLIT FRACTION
S205	MIXED	1.00000

COMPONENT = HYDROGEN

STREAM	SUBSTREAM	SPLIT FRACTION
S204	MIXED	0.00100000
S205	MIXED	0.99900

COMPONENT = WATER

STREAM	SUBSTREAM	SPLIT FRACTION
S204	MIXED	0.29000
S205	MIXED	0.71000

COMPONENT = CO

STREAM	SUBSTREAM	SPLIT FRACTION
S205	MIXED	1.00000

COMPONENT = CO2

STREAM	SUBSTREAM	SPLIT FRACTION
S204	MIXED	0.94000
S205	MIXED	0.060000

COMPONENT = METHANE

STREAM	SUBSTREAM	SPLIT FRACTION
S205	MIXED	1.00000

COMPONENT = ETHANE

STREAM	SUBSTREAM	SPLIT FRACTION
S205	MIXED	1.00000

COMPONENT = ETHENE

STREAM	SUBSTREAM	SPLIT FRACTION
S205	MIXED	1.00000

BLOCK: MX101 MODEL: MIXER

INLET STREAMS: S101 S116
OUTLET STREAM: S102
PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS

*** MASS AND ENERGY BALANCE ***

	IN	OUT	RELATIVE DIFF.
TOTAL BALANCE			
MOLE(LBMOL/HR)	21396.9	21396.9	0.00000

```
   MASS(LB/HR   )            385471.          385471.          0.00000
   ENTHALPY(BTU/HR  )     -0.259449E+10    -0.259449E+10    -0.183788E-15

                     ***  CO2 EQUIVALENT SUMMARY ***
  FEED STREAMS CO2E            0.00000      LB/HR
  PRODUCT STREAMS CO2E         0.00000      LB/HR
  NET STREAMS CO2E PRODUCTION  0.00000      LB/HR
  UTILITIES CO2E PRODUCTION    0.00000      LB/HR
  TOTAL CO2E PRODUCTION        0.00000      LB/HR

                          ***  INPUT DATA  ***
  TWO    PHASE      FLASH
  MAXIMUM NO. ITERATIONS                                    30
  CONVERGENCE TOLERANCE                                      0.000100000
  OUTLET PRESSURE:  MINIMUM OF INLET STREAM PRESSURES

BLOCK:  MX102    MODEL: MIXER
------------------------------
  INLET STREAMS:         S104        S103        S314
  OUTLET STREAM:         S105
  PROPERTY OPTION SET:   UNIQUAC   UNIQUAC / IDEAL GAS

                     ***  MASS AND ENERGY BALANCE  ***
                                  IN               OUT        RELATIVE DIFF.
  TOTAL BALANCE
   MOLE(LBMOL/HR)            30996.5          30996.5         -0.117367E-15
   MASS(LB/HR   )            807550.          807550.         -0.103508E-08
   ENTHALPY(BTU/HR  )     -0.256095E+10    -0.256095E+10     0.947987E-08

                     ***  CO2 EQUIVALENT SUMMARY ***
  FEED STREAMS CO2E            2.97781      LB/HR
  PRODUCT STREAMS CO2E         2.97781      LB/HR
  NET STREAMS CO2E PRODUCTION -0.351163E-06  LB/HR
  UTILITIES CO2E PRODUCTION    0.00000      LB/HR
  TOTAL CO2E PRODUCTION       -0.351163E-06  LB/HR

                          ***  INPUT DATA  ***
  TWO    PHASE      FLASH
  MAXIMUM NO. ITERATIONS                                    30
  CONVERGENCE TOLERANCE                                      0.000100000
  OUTLET PRESSURE:  MINIMUM OF INLET STREAM PRESSURES

BLOCK:  MX301    MODEL: MIXER
------------------------------
  INLET STREAMS:         S311        S4
  OUTLET STREAM:         S312
  PROPERTY OPTION SET:   UNIQUAC   UNIQUAC / IDEAL GAS

                     ***  MASS AND ENERGY BALANCE  ***
                                  IN               OUT        RELATIVE DIFF.
  TOTAL BALANCE
   MOLE(LBMOL/HR)             5240.37          5240.37          0.00000
   MASS(LB/HR   )             229716.          229716.         -0.253390E-15
   ENTHALPY(BTU/HR  )     -0.227995E+09    -0.227995E+09     0.392144E-15

                     ***  CO2 EQUIVALENT SUMMARY ***
  FEED STREAMS CO2E            3.30868      LB/HR
  PRODUCT STREAMS CO2E         3.30868      LB/HR
  NET STREAMS CO2E PRODUCTION  0.00000      LB/HR
  UTILITIES CO2E PRODUCTION    0.00000      LB/HR
  TOTAL CO2E PRODUCTION        0.00000      LB/HR

                          ***  INPUT DATA  ***
```

```
  TWO    PHASE      FLASH
  MAXIMUM NO. ITERATIONS                                    30
  CONVERGENCE TOLERANCE                                      0.000100000
  OUTLET PRESSURE:  MINIMUM OF INLET STREAM PRESSURES

BLOCK:  P101     MODEL: PUMP
------------------------------
  INLET STREAM:          2
  OUTLET STREAM:         S116
  PROPERTY OPTION SET:   UNIQUAC   UNIQUAC / IDEAL GAS

                     ***  MASS AND ENERGY BALANCE  ***
                                  IN               OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(LBMOL/HR)            19523.0          19523.0          0.00000
      MASS(LB/HR   )            351712.          351712.          0.00000
      ENTHALPY(BTU/HR  )     -0.236430E+10    -0.236424E+10    -0.236459E-04

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E             0.00000      LB/HR
   PRODUCT STREAMS CO2E          0.00000      LB/HR
   NET STREAMS CO2E PRODUCTION   0.00000      LB/HR
   UTILITIES CO2E PRODUCTION     0.00000      LB/HR
   TOTAL CO2E PRODUCTION         0.00000      LB/HR

                        ***  INPUT DATA  ***
   OUTLET PRESSURE  PSIA                                    72.5189
   DRIVER EFFICIENCY                                         1.00000

   FLASH SPECIFICATIONS:
   LIQUID PHASE CALCULATION
   NO FLASH PERFORMED
   MAXIMUM NUMBER OF ITERATIONS                             30
   TOLERANCE                                                 0.000100000

                         ***  RESULTS  ***
   VOLUMETRIC FLOW RATE  CUFT/HR                        5,990.91
   PRESSURE CHANGE  PSI                                    37.7098
   NPSH AVAILABLE   FT-LBF/LB                              69.3238
   FLUID POWER  HP                                         16.4303
   BRAKE POWER  HP                                         21.9719
   ELECTRICITY  KW                                         16.3844
   PUMP EFFICIENCY USED                                     0.74779
   NET WORK REQUIRED  HP                                   21.9719
   HEAD DEVELOPED FT-LBF/LB                                92.4959

BLOCK:  P301     MODEL: PUMP
------------------------------
  INLET STREAM:          S303
  OUTLET STREAM:         S304
  PROPERTY OPTION SET:   UNIQUAC   UNIQUAC / IDEAL GAS

                     ***  MASS AND ENERGY BALANCE  ***
                                  IN               OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(LBMOL/HR)             6613.87          6613.87          0.00000
      MASS(LB/HR   )             282428.          282428.          0.00000
      ENTHALPY(BTU/HR  )     -0.866823E+08    -0.858981E+08    -0.904687E-02

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E             3.30868      LB/HR
   PRODUCT STREAMS CO2E          3.30868      LB/HR
   NET STREAMS CO2E PRODUCTION   0.00000      LB/HR
```

```
 UTILITIES CO2E PRODUCTION     0.00000      LB/HR
 TOTAL CO2E PRODUCTION         0.00000      LB/HR

                         ***  INPUT DATA  ***
 OUTLET PRESSURE  PSIA                                    575.000
 DRIVER EFFICIENCY                                          1.00000

 FLASH SPECIFICATIONS:
 LIQUID PHASE CALCULATION
 NO FLASH PERFORMED
 MAXIMUM NUMBER OF ITERATIONS                               30
 TOLERANCE                                                  0.000100000

                          ***  RESULTS  ***
 VOLUMETRIC FLOW RATE  CUFT/HR                          9,476.08
 PRESSURE CHANGE  PSI                                     350.000
 NPSH AVAILABLE   FT-LBF/LB                                 0.0
 FLUID POWER  HP                                          241.209
 BRAKE POWER  HP                                          308.204
 ELECTRICITY  KW                                          229.827
 PUMP EFFICIENCY USED                                       0.78263
 NET WORK REQUIRED  HP                                    308.204
 HEAD DEVELOPED FT-LBF/LB                               1,691.03

BLOCK:  R101     MODEL: RSTOIC
------------------------------
  INLET STREAM:          S15
  OUTLET STREAM:         S108
  PROPERTY OPTION SET:   UNIQUAC   UNIQUAC / IDEAL GAS

                     ***  MASS AND ENERGY BALANCE  ***
                            IN           OUT       GENERATION   RELATIVE DIFF.
  TOTAL BALANCE
  MOLE(LBMOL/HR)          30996.5       33892.2       2895.75       0.00000
  MASS(LB/HR    )         807550.       807550.                    -0.144159E-15
  ENTHALPY(BTU/HR  )   -0.216583E+10 -0.200387E+10                  -0.747796E-01

                     ***  CO2 EQUIVALENT SUMMARY ***
  FEED STREAMS CO2E             2.97781      LB/HR
  PRODUCT STREAMS CO2E          5085.66      LB/HR
  NET STREAMS CO2E PRODUCTION   5082.68      LB/HR
  UTILITIES CO2E PRODUCTION     0.00000      LB/HR
  TOTAL CO2E PRODUCTION         5082.68      LB/HR

                         ***  INPUT DATA  ***
  STOICHIOMETRY MATRIX:

   REACTION #   1:
    SUBSTREAM MIXED   :
    PROPANE   -1.00    PROPENE    1.00    HYDROGEN   1.00

   REACTION #   2:
    SUBSTREAM MIXED   :
    PROPANE   -1.00    METHANE    1.00    ETHENE     1.00

   REACTION #   3:
    SUBSTREAM MIXED   :
    HYDROGEN  -1.00    ETHANE     1.00    ETHENE    -1.00


  REACTION CONVERSION SPECS: NUMBER=    3
    REACTION #   1:
    SUBSTREAM:MIXED    KEY COMP:PROPANE  CONV FRAC: 0.3130
```

```
  REACTION #   2:
  SUBSTREAM:MIXED    KEY COMP:PROPANE  CONV FRAC: 0.2000E-02
  REACTION #   3:
  SUBSTREAM:MIXED    KEY COMP:ETHENE   CONV FRAC: 0.3000


  TWO    PHASE  TP  FLASH
  SPECIFIED TEMPERATURE F                                  1,094.00
  SPECIFIED PRESSURE    PSIA                                  73.0000
  MAXIMUM NO. ITERATIONS                                      30
  CONVERGENCE TOLERANCE                                        0.000100000
  SERIES REACTIONS
  GENERATE COMBUSTION REACTIONS FOR FEED SPECIES             NO

                          ***  RESULTS  ***
  OUTLET TEMPERATURE    F                                     1094.0
  OUTLET PRESSURE       PSIA                                   73.000
  HEAT DUTY             BTU/HR                              0.16196E+09
  VAPOR FRACTION                                             1.0000


  REACTION EXTENTS:

     REACTION          REACTION
     NUMBER            EXTENT
                       LBMOL/HR
     1                  2886.9
     2                  12.673
     3                  3.8209

  V-L PHASE EQUILIBRIUM :

     COMP              F(I)          X(I)          Y(I)          K(I)
     PROPANE          0.18658       0.14371       0.18658       478.35
     PROPENE          0.95698E-01   0.59593E-01   0.95698E-01   591.66
     HYDROGEN         0.85066E-01   0.16392E-01   0.85066E-01   1912.1
     WATER            0.63190       0.77998       0.63190       298.51
     CO               0.14833E-07   0.48242E-08   0.14833E-07   1132.9
     CO2              0.15217E-05   0.37844E-06   0.15217E-05   1481.5
     METHANE          0.37397E-03   0.14687E-03   0.37397E-03   938.14
     ETHANE           0.11824E-03   0.60198E-04   0.11824E-03   723.68
     ETHENE           0.26305E-03   0.11334E-03   0.26305E-03   855.09

BLOCK:  R102     MODEL: RSTOIC
------------------------------
  INLET STREAMS:          S108        S109
  OUTLET STREAM:          1
  OUTLET HEAT STREAM:     S2
  PROPERTY OPTION SET:    UNIQUAC   UNIQUAC / IDEAL GAS


    ***************************************************************************
    *                                                                         *
    *     CONVERSION FRACTIONS OF ONE OR MORE COMPONENTS WERE MODIFIED        *
    *                                                                         *
    ***************************************************************************


                      ***  MASS AND ENERGY BALANCE  ***
                         IN           OUT       GENERATION   RELATIVE DIFF.
```

```
TOTAL BALANCE
MOLE(LBMOL/HR)          34642.2       35660.4       1018.15       0.00000
MASS(LB/HR   )          831549.       831549.                    0.279996E-15
ENTHALPY(BTU/HR  )   -0.199808E+10 -0.199808E+10                 -0.357972E-15

                   ***  CO2 EQUIVALENT SUMMARY ***
 FEED STREAMS CO2E             5085.66      LB/HR
 PRODUCT STREAMS CO2E          12430.5      LB/HR
 NET STREAMS CO2E PRODUCTION   7344.80      LB/HR
 UTILITIES CO2E PRODUCTION     0.00000      LB/HR
 TOTAL CO2E PRODUCTION         7344.80      LB/HR

                      ***  INPUT DATA  ***
STOICHIOMETRY MATRIX:

 REACTION #   1:
  SUBSTREAM MIXED   :
  PROPANE   -1.00    PROPENE    1.00    HYDROGEN   1.00

 REACTION #   2:
  SUBSTREAM MIXED   :
  PROPANE   -1.00    METHANE    1.00    ETHENE     1.00

 REACTION #   3:
  SUBSTREAM MIXED   :
  PROPANE   -1.00    OXYGEN    -5.00    WATER      4.00    CO2        3.00

 REACTION #   4:
  SUBSTREAM MIXED   :
  PROPANE   -1.00    OXYGEN    -3.50    WATER      4.00    CO         3.00

 REACTION #   5:
  SUBSTREAM MIXED   :
  HYDROGEN  -1.00    ETHANE     1.00    ETHENE    -1.00

 REACTION #   6:
  SUBSTREAM MIXED   :
  HYDROGEN  -1.00    OXYGEN   -0.500    WATER      1.00


REACTION CONVERSION SPECS: NUMBER=    5
  REACTION #   1:
  SUBSTREAM:MIXED    KEY COMP:PROPANE  CONV FRAC: 0.2238
  REACTION #   2:
  SUBSTREAM:MIXED    KEY COMP:PROPANE  CONV FRAC: 0.1100E-02
  REACTION #   3:
  SUBSTREAM:MIXED    KEY COMP:PROPANE  CONV FRAC: 0.8000E-02
  REACTION #   4:
  SUBSTREAM:MIXED    KEY COMP:PROPANE  CONV FRAC: 0.4000E-02
  REACTION #   5:
  SUBSTREAM:MIXED    KEY COMP:ETHENE   CONV FRAC: 0.3000


REACTION EXTENT SPECS: NUMBER=    1
  REACTION #   6: EXTENT=   983.9     LBMOL/HR



TWO    PHASE  TP  FLASH
SPECIFIED TEMPERATURE F                              1,094.00
SPECIFIED PRESSURE    PSIA                              56.3000
MAXIMUM NO. ITERATIONS                                  30
```

CONVERGENCE TOLERANCE 0.000100000
SERIES REACTIONS
GENERATE COMBUSTION REACTIONS FOR FEED SPECIES NO

*** RESULTS ***

OUTLET TEMPERATURE	F	1094.0
OUTLET PRESSURE	PSIA	56.300
HEAT DUTY	BTU/HR	-0.68346E+08
VAPOR FRACTION		1.0000

REACTION EXTENTS:

REACTION NUMBER	REACTION EXTENT LBMOL/HR
1	1414.9
2	5.3997
3	39.227
4	19.457
5	4.2945
6	971.53

V-L PHASE EQUILIBRIUM :

COMP	F(I)	X(I)	Y(I)	K(I)
PROPANE	0.13586	0.10058	0.13586	652.32
PROPENE	0.13063	0.78266E-01	0.13063	806.06
HYDROGEN	0.93162E-01	0.17794E-01	0.93162E-01	2528.6
WATER	0.63439	0.80160	0.63439	382.22
CO	0.16368E-02	0.52325E-03	0.16368E-02	1510.8
CO2	0.33015E-02	0.80380E-03	0.33015E-02	1983.7
METHANE	0.50684E-03	0.19539E-03	0.50684E-03	1252.8
ETHANE	0.23281E-03	0.11513E-03	0.23281E-03	976.57
ETHENE	0.28100E-03	0.11774E-03	0.28100E-03	1152.6

BLOCK: SP101 MODEL: FSPLIT

INLET STREAM: S1
OUTLET STREAMS: S3 2
PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS

*** MASS AND ENERGY BALANCE ***

	IN	OUT	RELATIVE DIFF.
TOTAL BALANCE			
MOLE(LBMOL/HR)	21692.2	21692.2	0.00000
MASS(LB/HR)	390791.	390791.	0.148948E-15
ENTHALPY(BTU/HR)	-0.262700E+10	-0.262700E+10	0.00000

*** CO2 EQUIVALENT SUMMARY ***

FEED STREAMS CO2E	0.00000	LB/HR
PRODUCT STREAMS CO2E	0.00000	LB/HR
NET STREAMS CO2E PRODUCTION	0.00000	LB/HR
UTILITIES CO2E PRODUCTION	0.00000	LB/HR
TOTAL CO2E PRODUCTION	0.00000	LB/HR

*** INPUT DATA ***

FRACTION OF FLOW STRM=S3 FRAC= 0.100000

*** RESULTS ***

```
 STREAM= S3             SPLIT=          0.100000     KEY=  0    STREAM-ORDER=   1
         2                              0.90000            0                    2

BLOCK:  T101     MODEL: COMPR
------------------------------
  INLET STREAM:          S111
  OUTLET STREAM:         S112
  PROPERTY OPTION SET:   UNIQUAC   UNIQUAC / IDEAL GAS

                     ***  MASS AND ENERGY BALANCE  ***
                                  IN               OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(LBMOL/HR)            35313.9          35313.9          0.00000
      MASS(LB/HR   )            824709.          824709.          0.00000
      ENTHALPY(BTU/HR  )     -0.236342E+10    -0.238191E+10    0.776595E-02

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            12430.4      LB/HR
   PRODUCT STREAMS CO2E         12430.4      LB/HR
   NET STREAMS CO2E PRODUCTION  0.00000      LB/HR
   UTILITIES CO2E PRODUCTION    0.00000      LB/HR
   TOTAL CO2E PRODUCTION        0.00000      LB/HR

                          ***  INPUT DATA  ***

  ISENTROPIC TURBINE
   OUTLET PRESSURE  PSIA                                    34.8091
   ISENTROPIC EFFICIENCY                                     0.72000
   MECHANICAL EFFICIENCY                                     1.00000

                          ***  RESULTS  ***

   INDICATED  HORSEPOWER REQUIREMENT  HP              -7,269.93
   BRAKE      HORSEPOWER REQUIREMENT  HP              -7,269.93
   NET WORK REQUIRED                  HP              -7,269.93
   POWER LOSSES                       HP                   0.0
   ISENTROPIC HORSEPOWER REQUIREMENT  HP             -10,097.1
   CALCULATED OUTLET TEMP  F                            419.503
   ISENTROPIC TEMPERATURE  F                            403.199
   EFFICIENCY (POLYTR/ISENTR) USED                       0.72000
   OUTLET VAPOR FRACTION                                 1.00000
   HEAD DEVELOPED,       FT-LBF/LB                   -24,241.6
   MECHANICAL EFFICIENCY USED                            1.00000
   INLET HEAT CAPACITY RATIO                             1.18360
   INLET VOLUMETRIC FLOW RATE , CUFT/HR             6,644,400.
   OUTLET VOLUMETRIC FLOW RATE, CUFT/HR             9,571,590.
   INLET  COMPRESSIBILITY FACTOR                         1.00000
   OUTLET COMPRESSIBILITY FACTOR                         1.00000
   AV. ISENT. VOL. EXPONENT                              1.18663
   AV. ISENT. TEMP EXPONENT                              1.18663
   AV. ACTUAL VOL. EXPONENT                              1.12578
   AV. ACTUAL TEMP EXPONENT                              1.12578
```

Stream Report

1 2 3 PURGE RECY

STREAM ID		1	2	3	PURGE	RECY
FROM :		R102	SP101	DC201	B1	B1
TO :		H000	P101	B2	B2	H303
SUBSTREAM: MIXED						
PHASE:		VAPOR	LIQUID	VAPOR	MIXED	MIXED
COMPONENTS: LBMOL/HR						
PROPANE		4844.7214	0.0	1.3546	482.2303	4340.0723
PROPENE		4658.3432	0.0	50.8589	39.6122	356.5097
HYDROGEN		3322.1880	0.0	3318.8400	6.6292-06	5.9663-05
OXYGEN		0.0	0.0	0.0	0.0	0.0
WATER		2.2623+04	1.9523+04	0.0	2.1610	19.4491
CO		58.3706	0.0	58.3698	5.5859-05	5.0273-04
CO2		117.7333	0.0	7.0066	5.7303-03	5.1573-02
METHANE		18.0743	0.0	17.8915	1.9617-04	1.7656-03
ETHANE		8.3020	0.0	8.0096	2.0723-02	0.1865
ETHENE		10.0206	0.0	9.9497	7.0584-03	6.3526-02
COMPONENTS: LB/HR						
PROPANE		2.1364+05	0.0	59.7320	2.1265+04	1.9138+05
PROPENE		1.9603+05	0.0	2140.1740	1666.9063	1.5002+04
HYDROGEN		6697.1324	0.0	6690.3832	1.3364-05	1.2027-04
OXYGEN		0.0	0.0	0.0	0.0	0.0
WATER		4.0755+05	3.5171+05	0.0	38.9311	350.3802
CO		1634.9850	0.0	1634.9603	1.5646-03	1.4082-02
CO2		5181.4191	0.0	308.3602	0.2522	2.2697
METHANE		289.9614	0.0	287.0284	3.1472-03	2.8324-02
ETHANE		249.6368	0.0	240.8459	0.6231	5.6082
ETHENE		281.1154	0.0	279.1268	0.1980	1.7821
TOTAL FLOW:						
LBMOL/HR		3.5660+04	1.9523+04	3472.2806	524.0372	4716.3350
LB/HR		8.3155+05	3.5171+05	1.1641+04	2.2972+04	2.0674+05
CUFT/HR		1.0561+07	5990.9099	5.0171+04	1.1278+05	1.0150+06
STATE VARIABLES:						
TEMP	F	1094.0000	173.8599	-96.1354	-28.8264	-28.8264
PRES	PSIA	56.3000	34.8091	270.0000	20.0000	20.0000
VFRAC		1.0000	0.0	1.0000	0.9306	0.9306
LFRAC		0.0	1.0000	0.0	6.9396-02	6.9396-02
SFRAC		0.0	0.0	0.0	0.0	0.0
ENTHALPY:						
BTU/LBMOL		-5.7947+04	-1.2110+05	-2412.5808	-4.3507+04	-4.3507+04
BTU/LB		-2485.0316	-6722.2463	-719.6493	-992.5094	-992.5094
BTU/HR		-2.0664+09	-2.3643+09	-8.3772+06	-2.2800+07	-2.0520+08
ENTROPY:						
BTU/LBMOL-R		-6.7185	-35.9555	-8.3778	-66.7457	-66.7457
BTU/LB-R		-0.2881	-1.9958	-2.4990	-1.5226	-1.5226
DENSITY:						
LBMOL/CUFT		3.3767-03	3.2588	6.9209-02	4.6465-03	4.6465-03
LB/CUFT		7.8740-02	58.7076	0.2320	0.2037	0.2037
AVG MW		23.3186	18.0153	3.3524	43.8358	43.8358

MIXED SUBSTREAM PROPERTIES:

*** ALL PHASES ***						
TEMP	F	1094.0000	173.8599	-96.1354	-28.8264	-28.8264
PRES	PSIA	56.3000	34.8091	270.0000	20.0000	20.0000
HFLMX	BTU/HR	-2.0664+09	-2.3643+09	-8.3772+06	-2.2800+07	-2.0520+08

S1 S101 S102 S103 S104

STREAM ID		S1	S101	S102	S103	S104
FROM :		H103	----	MX101	----	H101
TO :		SP101	MX101	H101	MX102	MX102
SUBSTREAM: MIXED						
PHASE:		LIQUID	LIQUID	LIQUID	VAPOR	VAPOR
COMPONENTS: LBMOL/HR						
PROPANE		0.0	0.0	0.0	4883.2391	0.0
PROPENE		0.0	0.0	0.0	0.0	0.0
HYDROGEN		0.0	0.0	0.0	0.0	0.0
OXYGEN		0.0	0.0	0.0	0.0	0.0
WATER		2.1692+04	1873.9292	2.1397+04	0.0	2.1397+04
CO		0.0	0.0	0.0	0.0	0.0
CO2		0.0	0.0	0.0	0.0	0.0
METHANE		0.0	0.0	0.0	0.0	0.0
ETHANE		0.0	0.0	0.0	0.0	0.0
ETHENE		0.0	0.0	0.0	0.0	0.0
COMPONENTS: LB/HR						
PROPANE		0.0	0.0	0.0	2.1533+05	0.0
PROPENE		0.0	0.0	0.0	0.0	0.0
HYDROGEN		0.0	0.0	0.0	0.0	0.0
OXYGEN		0.0	0.0	0.0	0.0	0.0
WATER		3.9079+05	3.3759+04	3.8547+05	0.0	3.8547+05
CO		0.0	0.0	0.0	0.0	0.0
CO2		0.0	0.0	0.0	0.0	0.0
METHANE		0.0	0.0	0.0	0.0	0.0
ETHANE		0.0	0.0	0.0	0.0	0.0
ETHENE		0.0	0.0	0.0	0.0	0.0
TOTAL FLOW:						
LBMOL/HR		2.1692+04	1873.9292	2.1397+04	4883.2391	2.1397+04
LB/HR		3.9079+05	3.3759+04	3.8547+05	2.1533+05	3.8547+05
CUFT/HR		6441.9834	544.0608	6533.9742	3.8781+05	2.9332+06
STATE VARIABLES:						
TEMP	F	176.0000	77.0000	165.7822	77.0000	466.6963
PRES	PSIA	34.8091	72.5189	72.5189	72.5189	72.5189
VFRAC		0.0	0.0	0.0	1.0000	1.0000
LFRAC		1.0000	1.0000	1.0000	0.0	0.0
SFRAC		0.0	0.0	0.0	0.0	0.0
ENTHALPY:						
BTU/LBMOL		-1.2110+05	-1.2287+05	-1.2126+05	-4.5004+04	-1.0076+05
BTU/LB		-6722.2463	-6820.4298	-6730.7001	-1020.5862	-5593.2896
BTU/HR		-2.6270+09	-2.3025+08	-2.5945+09	-2.1977+08	-2.1561+09
ENTROPY:						
BTU/LBMOL-R		-35.9414	-38.9652	-36.1949	-67.4897	-9.3117
BTU/LB-R		-1.9951	-2.1629	-2.0091	-1.5305	-0.5169
DENSITY:						
LBMOL/CUFT		3.3673	3.4443	3.2747	1.2592-02	7.2948-03
LB/CUFT		60.6632	62.0507	58.9950	0.5553	0.1314
AVG MW		18.0153	18.0153	18.0153	44.0965	18.0153
MIXED SUBSTREAM PROPERTIES:						
*** ALL PHASES ***						
TEMP	F	176.0000	77.0000	165.7822	77.0000	466.6963
PRES	PSIA	34.8091	72.5189	72.5189	72.5189	72.5189
HFLMX	BTU/HR	-2.6270+09	-2.3025+08	-2.5945+09	-2.1977+08	-2.1561+09

S105 S108 S109 S110 S111

STREAM ID	S105	S108	S109	S110	S111
FROM :	MX102	R101	----	H000	HX101

TO :	HX101	R102	R102	HX101	T101
MAX CONV. ERROR:	1.3573-06	0.0	0.0	1.4425-02	0.0
SUBSTREAM: MIXED					
PHASE:	VAPOR	VAPOR	VAPOR	VAPOR	VAPOR
COMPONENTS: LBMOL/HR					
PROPANE	9223.3119	6323.7425	0.0	4844.6952	4844.6952
PROPENE	356.5092	3243.4059	0.0	4633.5591	4633.5591
HYDROGEN	5.9663-05	2883.0758	0.0	3322.1622	3322.1622
OXYGEN	0.0	0.0	750.0000	0.0	0.0
WATER	2.1416+04	2.1416+04	0.0	2.2301+04	2.2301+04
CO	5.0273-04	5.0273-04	0.0	58.3703	58.3703
CO2	5.1573-02	5.1573-02	0.0	117.7321	117.7321
METHANE	1.7656-03	12.6746	0.0	18.0742	18.0742
ETHANE	0.1865	4.0074	0.0	8.2998	8.2998
ETHENE	6.3526-02	8.9154	0.0	10.0203	10.0203
COMPONENTS: LB/HR					
PROPANE	4.0672+05	2.7886+05	0.0	2.1363+05	2.1363+05
PROPENE	1.5002+04	1.3648+05	0.0	1.9498+05	1.9498+05
HYDROGEN	1.2027-04	5811.9348	0.0	6697.0804	6697.0804
OXYGEN	0.0	0.0	2.3999+04	0.0	0.0
WATER	3.8582+05	3.8582+05	0.0	4.0176+05	4.0176+05
CO	1.4082-02	1.4082-02	0.0	1634.9760	1634.9760
CO2	2.2697	2.2697	0.0	5181.3675	5181.3675
METHANE	2.8324-02	203.3355	0.0	289.9595	289.9595
ETHANE	5.6082	120.5015	0.0	249.5730	249.5730
ETHENE	1.7821	250.1119	0.0	281.1069	281.1069
TOTAL FLOW:					
LBMOL/HR	3.0996+04	3.3892+04	750.0000	3.5314+04	3.5314+04
LB/HR	8.0755+05	8.0755+05	2.3999+04	8.2471+05	8.2471+05
CUFT/HR	3.4307+06	7.7409+06	1.7130+05	1.2076+07	6.6444+06
STATE VARIABLES:					
TEMP F	288.2717	1094.0000	1094.0000	1210.7455	460.8083
PRES PSIA	72.5189	73.0000	73.0000	52.5000	52.5000
VFRAC	1.0000	1.0000	1.0000	1.0000	1.0000
LFRAC	0.0	0.0	0.0	0.0	0.0
SFRAC	0.0	0.0	0.0	0.0	0.0
ENTHALPY:					
BTU/LBMOL	-8.2621+04	-5.9125+04	7727.2183	-5.5737+04	-6.6926+04
BTU/LB	-3171.2595	-2481.4258	241.4846	-2386.6621	-2865.7580
BTU/HR	-2.5609+09	-2.0039+09	5.7954+06	-1.9683+09	-2.3634+09
ENTROPY:					
BTU/LBMOL-R	-24.7911	-8.9101	4.7795	-5.3986	-14.1825
BTU/LB-R	-0.9516	-0.3740	0.1494	-0.2312	-0.6073
DENSITY:					
LBMOL/CUFT	9.0350-03	4.3783-03	4.3783-03	2.9243-03	5.3148-03
LB/CUFT	0.2354	0.1043	0.1401	6.8294-02	0.1241
AVG MW	26.0529	23.8270	31.9988	23.3537	23.3537

MIXED SUBSTREAM PROPERTIES:

*** ALL PHASES ***						
TEMP	F	288.2717	1094.0000	1094.0000	1210.7455	460.8083
PRES	PSIA	72.5189	73.0000	73.0000	52.5000	52.5000
HFLMX	BTU/HR	-2.5609+09	-2.0039+09	5.7954+06	-1.9688+09	-2.3634+09

S112 S114 S116 S15 S202

STREAM ID	S112	S114	S116	S15	S202
FROM :	T101	H103	P101	HX101	AD201
TO :	H103	AD201	MX101	R101	----

SUBSTREAM: MIXED PHASE:		VAPOR	VAPOR	LIQUID	VAPOR	LIQUID
COMPONENTS: LBMOL/HR						
PROPANE		4844.6952	4844.6952	0.0	9223.3119	0.0
PROPENE		4633.5591	4633.5591	0.0	356.5092	0.0
HYDROGEN		3322.1622	3322.1622	0.0	5.9663-05	0.0
OXYGEN		0.0	0.0	0.0	0.0	0.0
WATER		2.2301+04	608.7342	1.9523+04	2.1416+04	578.2975
CO		58.3703	58.3703	0.0	5.0273-04	0.0
CO2		117.7321	117.7321	0.0	5.1573-02	0.0
METHANE		18.0742	18.0742	0.0	1.7656-03	0.1807
ETHANE		8.2998	8.2998	0.0	0.1865	8.2998-02
ETHENE		10.0203	10.0203	0.0	6.3526-02	0.0
COMPONENTS: LB/HR						
PROPANE		2.1363+05	2.1363+05	0.0	4.0672+05	0.0
PROPENE		1.9498+05	1.9498+05	0.0	1.5002+04	0.0
HYDROGEN		6697.0804	6697.0804	0.0	1.2027-04	0.0
OXYGEN		0.0	0.0	0.0	0.0	0.0
WATER		4.0176+05	1.0967+04	3.5171+05	3.8582+05	1.0418+04
CO		1634.9760	1634.9760	0.0	1.4082-02	0.0
CO2		5181.3675	5181.3675	0.0	2.2697	0.0
METHANE		289.9595	289.9595	0.0	2.8324-02	2.8996
ETHANE		249.5730	249.5730	0.0	5.6082	2.4957
ETHENE		281.1069	281.1069	0.0	1.7821	0.0
TOTAL FLOW:						
LBMOL/HR		3.5314+04	1.3622+04	1.9523+04	3.0996+04	578.5612
LB/HR		8.2471+05	4.3392+05	3.5171+05	8.0755+05	1.0424+04
CUFT/HR		9.5716+06	2.6695+06	5991.4609	7.1265+06	177.9018
STATE VARIABLES:						
TEMP	F	419.5034	176.0000	174.0112	1094.0000	176.0000
PRES	PSIA	34.8091	34.8091	72.5189	72.5189	34.8091
VFRAC		1.0000	1.0000	0.0	1.0000	0.0
LFRAC		0.0	0.0	1.0000	0.0	1.0000
SFRAC		0.0	0.0	0.0	0.0	0.0
ENTHALPY:						
BTU/LBMOL		-6.7450+04	-1.7973+04	-1.2110+05	-6.9874+04	-1.2102+05
BTU/LB		-2888.1876	-564.1984	-6722.0873	-2681.9833	-6717.3352
BTU/HR		-2.3819+09	-2.4482+08	-2.3642+09	-2.1658+09	-7.0019+07
ENTROPY:						
BTU/LBMOL-R		-13.9486	-31.5497	-35.9511	-13.4731	-35.8847
BTU/LB-R		-0.5973	-0.9904	-1.9956	-0.5171	-1.9918
DENSITY:						
LBMOL/CUFT		3.6894-03	5.1027-03	3.2585	4.3495-03	3.2521
LB/CUFT		8.6162-02	0.1625	58.7022	0.1133	58.5918
AVG MW		23.3537	31.8550	18.0153	26.0529	18.0164

MIXED SUBSTREAM PROPERTIES:

*** ALL PHASES ***						
TEMP	F	419.5034	176.0000	174.0112	1094.0000	176.0000
PRES	PSIA	34.8091	34.8091	72.5189	72.5189	34.8091
HFLMX	BTU/HR	-2.3819+09	-2.4482+08	-2.3642+09	-2.1658+09	-7.0019+07

S203 S204 S205 S206 S207

STREAM ID	S203	S204	S205	S206	S207
FROM :	AD201	MEA201	MEA201	C201	C202
TO :	MEA201	----	C201	C202	DC201

SUBSTREAM: MIXED PHASE:	VAPOR	VAPOR	VAPOR	VAPOR	VAPOR

COMPONENTS: LBMOL/HR					
PROPANE	4844.6952	0.0	4844.6952	4844.6952	4844.6952
PROPENE	4633.5591	0.0	4633.5591	4633.5591	4633.5591
HYDROGEN	3322.1622	3.3222	3318.8401	3318.8401	3318.8401
OXYGEN	0.0	0.0	0.0	0.0	0.0
WATER	30.4367	8.8266	21.6101	21.6101	21.6101
CO	58.3703	0.0	58.3703	58.3703	58.3703
CO2	117.7321	110.6682	7.0639	7.0639	7.0639
METHANE	17.8934	0.0	17.8934	17.8934	17.8934
ETHANE	8.2168	0.0	8.2168	8.2168	8.2168
ETHENE	10.0203	0.0	10.0203	10.0203	10.0203
COMPONENTS: LB/HR					
PROPANE	2.1363+05	0.0	2.1363+05	2.1363+05	2.1363+05
PROPENE	1.9498+05	0.0	1.9498+05	1.9498+05	1.9498+05
HYDROGEN	6697.0804	6.6971	6690.3833	6690.3833	6690.3833
OXYGEN	0.0	0.0	0.0	0.0	0.0
WATER	548.3259	159.0145	389.3114	389.3114	389.3114
CO	1634.9760	0.0	1634.9760	1634.9760	1634.9760
CO2	5181.3675	4870.4854	310.8820	310.8820	310.8820
METHANE	287.0599	0.0	287.0599	287.0599	287.0599
ETHANE	247.0773	0.0	247.0773	247.0773	247.0773
ETHENE	281.1069	0.0	281.1069	281.1069	281.1069
TOTAL FLOW:					
LBMOL/HR	1.3043+04	122.8170	1.2920+04	1.2920+04	1.2920+04
LB/HR	4.2349+05	5036.1970	4.1846+05	4.1846+05	4.1846+05
CUFT/HR	2.5561+06	2.4069+04	2.5320+06	1.0453+06	4.0814+05
STATE VARIABLES:					
TEMP F	176.0000	176.0000	176.0000	294.1946	423.4221
PRES PSIA	34.8091	34.8091	34.8091	100.0000	300.0000
VFRAC	1.0000	1.0000	1.0000	1.0000	1.0000
LFRAC	0.0	0.0	0.0	0.0	0.0
SFRAC	0.0	0.0	0.0	0.0	0.0
ENTHALPY:					
BTU/LBMOL	-1.4195+04	-1.5902+05	-1.2818+04	-1.0843+04	-8416.4966
BTU/LB	-437.1884	-3877.9452	-395.7785	-334.7887	-259.8669
BTU/HR	-1.8515+08	-1.9530+07	-1.6562+08	-1.4010+08	-1.0874+08
ENTROPY:					
BTU/LBMOL-R	-32.8089	0.4358	-33.2208	-32.4714	-31.6865
BTU/LB-R	-1.0105	1.0628-02	-1.0257	-1.0026	-0.9783
DENSITY:					
LBMOL/CUFT	5.1027-03	5.1027-03	5.1027-03	1.2361-02	3.1656-02
LB/CUFT	0.1657	0.2092	0.1653	0.4003	1.0253
AVG MW	32.4689	41.0057	32.3877	32.3877	32.3877

MIXED SUBSTREAM PROPERTIES:

*** ALL PHASES ***					
TEMP F	176.0000	176.0000	176.0000	294.1946	423.4221
PRES PSIA	34.8091	34.8091	34.8091	100.0000	300.0000
HFLMX BTU/HR	-1.8515+08	-1.9530+07	-1.6562+08	-1.4010+08	-1.0874+08

S3 S301 S302 S303 S304

STREAM ID	S3	S301	S302	S303	S304
FROM :	SP101	DC201	DC301	DC301	P301
TO :	----	DC301	B6	P301	HX301
SUBSTREAM: MIXED					
PHASE:	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID
COMPONENTS: LBMOL/HR					
PROPANE	0.0	4843.3406	2801.5579	2041.7827	2041.7827
PROPENE	0.0	4582.7003	10.9528	4571.7475	4571.7475

HYDROGEN		0.0	6.6292-05	0.0	6.6292-05	6.6292-05
OXYGEN		0.0	0.0	0.0	0.0	0.0
WATER		2169.2211	21.6101	21.6101	0.0	0.0
CO		0.0	5.5859-04	0.0	5.5859-04	5.5859-04
CO2		0.0	5.7303-02	0.0	5.7303-02	5.7303-02
METHANE		0.0	1.9617-03	0.0	1.9617-03	1.9617-03
ETHANE		0.0	0.2072	8.4722-28	0.2072	0.2072
ETHENE		0.0	7.0584-02	0.0	7.0584-02	7.0584-02
COMPONENTS: LB/HR						
PROPANE		0.0	2.1357+05	1.2354+05	9.0036+04	9.0036+04
PROPENE		0.0	1.9284+05	460.8995	1.9238+05	1.9238+05
HYDROGEN		0.0	1.3364-04	0.0	1.3364-04	1.3364-04
OXYGEN		0.0	0.0	0.0	0.0	0.0
WATER		3.9079+04	389.3114	389.3114	0.0	0.0
CO		0.0	1.5646-02	0.0	1.5646-02	1.5646-02
CO2		0.0	2.5219	2.7305-34	2.5219	2.5219
METHANE		0.0	3.1472-02	0.0	3.1472-02	3.1472-02
ETHANE		0.0	6.2314	2.5476-26	6.2314	6.2314
ETHENE		0.0	1.9802	1.4771-35	1.9802	1.9802
TOTAL FLOW:						
LBMOL/HR		2169.2211	9447.9886	2834.1208	6613.8679	6613.8679
LB/HR		3.9079+04	4.0682+05	1.2439+05	2.8243+05	2.8243+05
CUFT/HR		665.6567	1.4441+04	4416.5585	9476.0785	9538.6338
STATE VARIABLES:						
TEMP	F	173.8599	124.8463	121.1944	102.9747	105.9465
PRES	PSIA	34.8091	281.9800	244.6800	225.0000	575.0000
VFRAC		0.0	0.0	0.0	0.0	0.0
LFRAC		1.0000	1.0000	1.0000	1.0000	1.0000
SFRAC		0.0	0.0	0.0	0.0	0.0
ENTHALPY:						
BTU/LBMOL		-1.2110+05	-2.3480+04	-4.9982+04	-1.3106+04	-1.2988+04
BTU/LB		-6722.2463	-545.3003	-1138.8023	-306.9180	-304.1413
BTU/HR		-2.6270+08	-2.2184+08	-1.4165+08	-8.6682+07	-8.5898+07
ENTROPY:						
BTU/LBMOL-R		-35.9555	-61.3611	-77.2836	-56.7877	-56.5991
BTU/LB-R		-1.9958	-1.4251	-1.7609	-1.3298	-1.3254
DENSITY:						
LBMOL/CUFT		3.2588	0.6543	0.6417	0.6980	0.6934
LB/CUFT		58.7076	28.1711	28.1643	29.8043	29.6089
AVG MW		18.0153	43.0586	43.8899	42.7024	42.7024

MIXED SUBSTREAM PROPERTIES:

*** ALL PHASES ***						
TEMP	F	173.8599	124.8463	121.1944	102.9747	105.9465
PRES	PSIA	34.8091	281.9800	244.6800	225.0000	575.0000
HFLMX	BTU/HR	-2.6270+08	-2.2184+08	-1.4165+08	-8.6682+07	-8.5898+07

S305 S306 S307 S308 S309

STREAM ID	S305	S306	S307	S308	S309
FROM :	HX301	H301	M301	C302	C303
TO :	H301	M301	C302	C303	HX301
SUBSTREAM: MIXED					
PHASE:	LIQUID	VAPOR	VAPOR	VAPOR	VAPOR
COMPONENTS: LBMOL/HR					
PROPANE	2041.7827	2041.7827	21.0380	21.0380	21.0380
PROPENE	4571.7475	4571.7475	4186.5784	4186.5784	4186.5784
HYDROGEN	6.6292-05	6.6292-05	0.0	0.0	0.0
OXYGEN	0.0	0.0	0.0	0.0	0.0
WATER	0.0	0.0	0.0	0.0	0.0

CO	5.5859-04	5.5859-04	0.0	0.0	0.0
CO2	5.7303-02	5.7303-02	0.0	0.0	0.0
METHANE	1.9617-03	1.9617-03	0.0	0.0	0.0
ETHANE	0.2072	0.2072	0.0	0.0	0.0
ETHENE	7.0584-02	7.0584-02	0.0	0.0	0.0
COMPONENTS: LB/HR					
PROPANE	9.0036+04	9.0036+04	927.7032	927.7032	927.7032
PROPENE	1.9238+05	1.9238+05	1.7617+05	1.7617+05	1.7617+05
HYDROGEN	1.3364-04	1.3364-04	0.0	0.0	0.0
OXYGEN	0.0	0.0	0.0	0.0	0.0
WATER	0.0	0.0	0.0	0.0	0.0
CO	1.5646-02	1.5646-02	0.0	0.0	0.0
CO2	2.5219	2.5219	0.0	0.0	0.0
METHANE	3.1472-02	3.1472-02	0.0	0.0	0.0
ETHANE	6.2314	6.2314	0.0	0.0	0.0
ETHENE	1.9802	1.9802	0.0	0.0	0.0
TOTAL FLOW:					
LBMOL/HR	6613.8679	6613.8679	4207.6164	4207.6164	4207.6164
LB/HR	2.8243+05	2.8243+05	1.7710+05	1.7710+05	1.7710+05
CUFT/HR	9619.8001	8.8463+04	5.6279+04	1.2493+06	1.4412+05
STATE VARIABLES:					
TEMP F	109.6769	257.0000	257.0000	93.6757	338.2659
PRES PSIA	575.0000	575.0000	575.0000	20.0000	250.0000
VFRAC	0.0	1.0000	1.0000	1.0000	1.0000
LFRAC	1.0000	0.0	0.0	0.0	0.0
SFRAC	0.0	0.0	0.0	0.0	0.0
ENTHALPY:					
BTU/LBMOL	-1.2836+04	-4621.4917	1.1552+04	8689.9830	1.3171+04
BTU/LB	-300.6006	-108.2254	274.4508	206.4584	312.9268
BTU/HR	-8.4898+07	-3.0566+07	4.8606+07	3.6564+07	5.5420+07
ENTROPY:					
BTU/LBMOL-R	-56.3604	-44.1809	-36.3527	-34.1963	-32.5596
BTU/LB-R	-1.3198	-1.0346	-0.8637	-0.8124	-0.7736
DENSITY:					
LBMOL/CUFT	0.6875	7.4764-02	7.4764-02	3.3680-03	2.9195-02
LB/CUFT	29.3591	3.1926	3.1469	0.1418	1.2289
AVG MW	42.7024	42.7024	42.0907	42.0907	42.0907

MIXED SUBSTREAM PROPERTIES:

*** ALL PHASES ***					
TEMP F	109.6769	257.0000	257.0000	93.6757	338.2659
PRES PSIA	575.0000	575.0000	575.0000	20.0000	250.0000
HFLMX BTU/HR	-8.4898+07	-3.0566+07	4.8606+07	3.6564+07	5.5420+07

S310 S311 S312 S313 S314

STREAM ID	S310	S311	S312	S313	S314
FROM :	M301	C301	MX301	H303	C304
TO :	C301	MX301	B1	C304	MX102
SUBSTREAM: MIXED					
PHASE:	VAPOR	VAPOR	MIXED	VAPOR	VAPOR
COMPONENTS: LBMOL/HR					
PROPANE	2020.7447	2020.7447	4822.3026	4340.0723	4340.0723
PROPENE	385.1691	385.1691	396.1219	356.5097	356.5097
HYDROGEN	6.6292-05	6.6292-05	6.6292-05	5.9663-05	5.9663-05
OXYGEN	0.0	0.0	0.0	0.0	0.0
WATER	0.0	0.0	21.6101	19.4491	19.4491
CO	5.5859-04	5.5859-04	5.5859-04	5.0273-04	5.0273-04
CO2	5.7303-02	5.7303-02	5.7303-02	5.1573-02	5.1573-02
METHANE	1.9617-03	1.9617-03	1.9617-03	1.7656-03	1.7656-03

ETHANE	0.2072	0.2072	0.2072	0.1865	0.1865
ETHENE	7.0584-02	7.0584-02	7.0584-02	6.3526-02	6.3526-02
COMPONENTS: LB/HR					
PROPANE	8.9108+04	8.9108+04	2.1265+05	1.9138+05	1.9138+05
PROPENE	1.6208+04	1.6208+04	1.6669+04	1.5002+04	1.5002+04
HYDROGEN	1.3364-04	1.3364-04	1.3364-04	1.2027-04	1.2027-04
OXYGEN	0.0	0.0	0.0	0.0	0.0
WATER	0.0	0.0	389.3114	350.3802	350.3802
CO	1.5646-02	1.5646-02	1.5646-02	1.4082-02	1.4082-02
CO2	2.5219	2.5219	2.5219	2.2697	2.2697
METHANE	3.1472-02	3.1472-02	3.1472-02	2.8324-02	2.8324-02
ETHANE	6.2314	6.2314	6.2314	5.6082	5.6082
ETHENE	1.9802	1.9802	1.9802	1.7821	1.7821
TOTAL FLOW:					
LBMOL/HR	2406.2515	2406.2515	5240.3723	4716.3350	4716.3350
LB/HR	1.0533+05	1.0533+05	2.2972+05	2.0674+05	2.0674+05
CUFT/HR	3.2185+04	7.3548+05	1.1278+06	1.3445+06	4.4694+05
STATE VARIABLES:					
TEMP F	257.0000	109.9772	-28.8264	71.6000	180.7066
PRES PSIA	575.0000	20.0000	20.0000	20.0000	72.5189
VFRAC	1.0000	1.0000	0.9306	1.0000	1.0000
LFRAC	0.0	0.0	6.9396-02	0.0	0.0
SFRAC	0.0	0.0	0.0	0.0	0.0
ENTHALPY:					
BTU/LBMOL	-3.2902+04	-3.5827+04	-4.3507+04	-4.1282+04	-3.9253+04
BTU/LB	-751.6762	-818.4816	-992.5094	-941.7367	-895.4494
BTU/HR	-7.9172+07	-8.6208+07	-2.2800+08	-1.9470+08	-1.8513+08
ENTROPY:					
BTU/LBMOL-R	-60.2607	-58.1411	-66.7457	-62.0035	-61.0957
BTU/LB-R	-1.3767	-1.3283	-1.5226	-1.4144	-1.3937
DENSITY:					
LBMOL/CUFT	7.4764-02	3.2717-03	4.6465-03	3.5080-03	1.0553-02
LB/CUFT	3.2726	0.1432	0.2037	0.1538	0.4626
AVG MW	43.7721	43.7721	43.8358	43.8358	43.8358

MIXED SUBSTREAM PROPERTIES:

*** ALL PHASES ***					
TEMP F	257.0000	109.9772	-28.8264	71.6000	180.7066
PRES PSIA	575.0000	20.0000	20.0000	20.0000	72.5189
HFLMX BTU/HR	-7.9172+07	-8.6208+07	-2.2800+08	-1.9470+08	-1.8513+08

S315 S316 S4 S6 S7

STREAM ID	S315	S316	S4	S6	S7
FROM :	HX301	H302	B6	B2	----
TO :	H302	----	MX301	----	B2
SUBSTREAM: MIXED					
PHASE:	VAPOR	LIQUID	LIQUID	VAPOR	VAPOR
COMPONENTS: LBMOL/HR					
PROPANE	21.0380	21.0380	2801.5579	0.0	0.0
PROPENE	4186.5784	4186.5784	10.9528	0.0	0.0
HYDROGEN	0.0	0.0	0.0	0.0	0.0
OXYGEN	0.0	0.0	0.0	2392.5913	7000.0000
WATER	0.0	0.0	21.6101	5606.5414	0.0
CO	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	1841.4157	0.0
METHANE	0.0	0.0	0.0	0.0	0.0
ETHANE	0.0	0.0	8.4722-28	0.0	0.0
ETHENE	0.0	0.0	0.0	0.0	0.0
COMPONENTS: LB/HR					

PROPANE		927.7032	927.7032	1.2354+05	0.0	0.0
PROPENE		1.7617+05	1.7617+05	460.8995	0.0	0.0
HYDROGEN		0.0	0.0	0.0	0.0	0.0
OXYGEN		0.0	0.0	0.0	7.6560+04	2.2399+05
WATER		0.0	0.0	389.3114	1.0100+05	0.0
CO		0.0	0.0	0.0	0.0	0.0
CO2		0.0	0.0	2.7305-34	8.1040+04	0.0
METHANE		0.0	0.0	0.0	0.0	0.0
ETHANE		0.0	0.0	2.5476-26	0.0	0.0
ETHENE		0.0	0.0	1.4771-35	0.0	0.0
TOTAL FLOW:						
LBMOL/HR		4207.6164	4207.6164	2834.1208	9840.5485	7000.0000
LB/HR		1.7710+05	1.7710+05	1.2439+05	2.5860+05	2.2399+05
CUFT/HR		1.4203+05	5849.6963	4405.1185	1.1161+07	2.7067+06
STATE VARIABLES:						
TEMP	F	326.7204	100.0000	120.1047	1094.0000	70.0000
PRES	PSIA	250.0000	250.0000	20.0000	14.7000	14.7000
VFRAC		1.0000	0.0	0.0	1.0000	1.0000
LFRAC		0.0	1.0000	1.0000	0.0	0.0
SFRAC		0.0	0.0	0.0	0.0	0.0
ENTHALPY:						
BTU/LBMOL		1.2934+04	3161.5962	-5.0029+04	-8.1899+04	-49.0505
BTU/LB		307.2803	75.1139	-1139.8679	-3116.4657	-1.5329
BTU/HR		5.4420+07	1.3303+07	-1.4179+08	-8.0593+08	-3.4335+05
ENTROPY:						
BTU/LBMOL-R		-32.8596	-48.9159	-77.3556	5.2575	-9.2547-02
BTU/LB-R		-0.7807	-1.1622	-1.7625	0.2001	-2.8922-03
DENSITY:						
LBMOL/CUFT		2.9624-02	0.7193	0.6434	8.8166-04	2.5862-03
LB/CUFT		1.2469	30.2753	28.2374	2.3170-02	8.2754-02
AVG MW		42.0907	42.0907	43.8899	26.2794	31.9988

MIXED SUBSTREAM PROPERTIES:

*** ALL PHASES ***						
TEMP	F	326.7204	100.0000	120.1047	1094.0000	70.0000
PRES	PSIA	250.0000	250.0000	20.0000	14.7000	14.7000
HFLMX	BTU/HR	5.4420+07	1.3303+07	-1.4179+08	-8.0593+08	-3.4335+05

S10 S11 S12 S13 S14

STREAM ID		S10	S11	S12	S13	S14
FROM :		B3	B3	B3	B3	B3
TO :		----	----	----	----	----
CLASS:		HEAT	HEAT	HEAT	HEAT	HEAT
STREAM ATTRIBUTES:						
HEAT						
Q	BTU/HR	5.3007+07	2.2034+08	5.4315+07	1.1345+07	1.6196+08
TBEG	F	7.1795	7.1795	7.1795	7.1795	7.1795
TEND	F	1094.0000	1094.0000	1094.0000	1094.0000	1094.0000

S16 S2 S8 S9

STREAM ID		S16	S2	S8	S9
FROM :		----	R102	B2	B3
TO :		H101	H000	B3	H101
CLASS:		HEAT	HEAT	HEAT	HEAT
STREAM ATTRIBUTES:					
HEAT					

Q	BTU/HR	1.6500+08	6.8346+07	7.7441+08	2.7344+08
TBEG	F	MISSING	1094.0000	7.1795	7.1795
TEND	F	MISSING	1094.0000	1094.0000	1094.0000

1
-

STREAM ID 1
FROM : R102
TO : H000

SUBSTREAM: MIXED
PHASE: VAPOR
COMPONENTS: LBMOL/HR

PROPANE	4844.7214
PROPENE	4658.3432
HYDROGEN	3322.1880
OXYGEN	0.0
WATER	2.2623+04
CO	58.3706
CO2	117.7333
METHANE	18.0743
ETHANE	8.3020
ETHENE	10.0206

COMPONENTS: LB/HR

PROPANE	2.1364+05
PROPENE	1.9603+05
HYDROGEN	6697.1324
OXYGEN	0.0
WATER	4.0755+05
CO	1634.9850
CO2	5181.4191
METHANE	289.9614
ETHANE	249.6368
ETHENE	281.1154

TOTAL FLOW:

LBMOL/HR	3.5660+04
LB/HR	8.3155+05
CUFT/HR	1.0561+07

STATE VARIABLES:

TEMP	F	1094.0000
PRES	PSIA	56.3000
VFRAC		1.0000
LFRAC		0.0
SFRAC		0.0

ENTHALPY:

BTU/LBMOL	-5.7947+04
BTU/LB	-2485.0316
BTU/HR	-2.0664+09

ENTROPY:

BTU/LBMOL-R	-6.7185
BTU/LB-R	-0.2881

DENSITY:

LBMOL/CUFT	3.3767-03
LB/CUFT	7.8740-02

AVG MW 23.3186

MIXED SUBSTREAM PROPERTIES:

*** ALL PHASES ***

TEMP	F	1094.0000
PRES	PSIA	56.3000
HFLMX	BTU/HR	-2.0664+09

```
2
-

STREAM ID                2
FROM :                   SP101
TO   :                   P101

SUBSTREAM: MIXED
PHASE:                   LIQUID
COMPONENTS: LBMOL/HR
  PROPANE                 0.0
  PROPENE                 0.0
  HYDROGEN                0.0
  OXYGEN                  0.0
  WATER                1.9523+04
  CO                      0.0
  CO2                     0.0
  METHANE                 0.0
  ETHANE                  0.0
  ETHENE                  0.0
COMPONENTS: LB/HR
  PROPANE                 0.0
  PROPENE                 0.0
  HYDROGEN                0.0
  OXYGEN                  0.0
  WATER                3.5171+05
  CO                      0.0
  CO2                     0.0
  METHANE                 0.0
  ETHANE                  0.0
  ETHENE                  0.0
TOTAL FLOW:
  LBMOL/HR             1.9523+04
  LB/HR                3.5171+05
  CUFT/HR              5990.9099
STATE VARIABLES:
  TEMP   F              173.8599
  PRES   PSIA            34.8091
  VFRAC                   0.0
  LFRAC                   1.0000
  SFRAC                   0.0
ENTHALPY:
  BTU/LBMOL           -1.2110+05
  BTU/LB              -6722.2463
  BTU/HR              -2.3643+09
ENTROPY:
  BTU/LBMOL-R           -35.9555
  BTU/LB-R               -1.9958
DENSITY:
  LBMOL/CUFT              3.2588
  LB/CUFT                58.7076
AVG MW                   18.0153

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F              173.8599
PRES     PSIA            34.8091
HFLMX    BTU/HR       -2.3643+09

3
-
```

```
STREAM ID                3
FROM :                   DC201
TO   :                   B2

SUBSTREAM: MIXED
PHASE:                   VAPOR
COMPONENTS: LBMOL/HR
  PROPANE                 1.3546
  PROPENE                50.8589
  HYDROGEN             3318.8400
  OXYGEN                  0.0
  WATER                   0.0
  CO                     58.3698
  CO2                     7.0066
  METHANE                17.8915
  ETHANE                  8.0096
  ETHENE                  9.9497
COMPONENTS: LB/HR
  PROPANE                59.7320
  PROPENE              2140.1740
  HYDROGEN             6690.3832
  OXYGEN                  0.0
  WATER                   0.0
  CO                   1634.9603
  CO2                   308.3602
  METHANE               287.0284
  ETHANE                240.8459
  ETHENE                279.1268
TOTAL FLOW:
  LBMOL/HR             3472.2806
  LB/HR                1.1641+04
  CUFT/HR              5.0171+04
STATE VARIABLES:
  TEMP    F             -96.1354
  PRES    PSIA          270.0000
  VFRAC                   1.0000
  LFRAC                   0.0
  SFRAC                   0.0
ENTHALPY:
  BTU/LBMOL           -2412.5808
  BTU/LB               -719.6493
  BTU/HR              -8.3772+06
ENTROPY:
  BTU/LBMOL-R             -8.3778
  BTU/LB-R                -2.4990
DENSITY:
  LBMOL/CUFT           6.9209-02
  LB/CUFT                 0.2320
AVG MW                    3.3524

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F              -96.1354
PRES     PSIA           270.0000
HFLMX    BTU/HR        -8.3772+06

PURGE
-----

STREAM ID                PURGE
FROM :                   B1
```

```
TO   :                    B2

SUBSTREAM: MIXED
PHASE:                    MIXED
COMPONENTS: LBMOL/HR
  PROPANE                482.2303
  PROPENE                 39.6122
  HYDROGEN              6.6292-06
  OXYGEN                    0.0
  WATER                     2.1610
  CO                    5.5859-05
  CO2                   5.7303-03
  METHANE               1.9617-04
  ETHANE                2.0723-02
  ETHENE                7.0584-03
COMPONENTS: LB/HR
  PROPANE               2.1265+04
  PROPENE               1666.9063
  HYDROGEN              1.3364-05
  OXYGEN                    0.0
  WATER                   38.9311
  CO                    1.5646-03
  CO2                       0.2522
  METHANE               3.1472-03
  ETHANE                    0.6231
  ETHENE                    0.1980
TOTAL FLOW:
  LBMOL/HR               524.0372
  LB/HR                 2.2972+04
  CUFT/HR               1.1278+05
STATE VARIABLES:
  TEMP    F              -28.8264
  PRES    PSIA            20.0000
  VFRAC                    0.9306
  LFRAC                 6.9396-02
  SFRAC                     0.0
ENTHALPY:
  BTU/LBMOL            -4.3507+04
  BTU/LB                -992.5094
  BTU/HR               -2.2800+07
ENTROPY:
  BTU/LBMOL-R            -66.7457
  BTU/LB-R                -1.5226
DENSITY:
  LBMOL/CUFT            4.6465-03
  LB/CUFT                   0.2037
AVG MW                    43.8358

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F              -28.8264
PRES     PSIA            20.0000
HFLMX    BTU/HR       -2.2800+07

RECY
----

STREAM ID                 RECY
FROM :                    B1
TO   :                    H303

SUBSTREAM: MIXED
```

```
PHASE:                    MIXED
COMPONENTS: LBMOL/HR
  PROPANE               4340.0723
  PROPENE                356.5097
  HYDROGEN              5.9663-05
  OXYGEN                   0.0
  WATER                   19.4491
  CO                    5.0273-04
  CO2                   5.1573-02
  METHANE               1.7656-03
  ETHANE                   0.1865
  ETHENE                6.3526-02
COMPONENTS: LB/HR
  PROPANE               1.9138+05
  PROPENE               1.5002+04
  HYDROGEN              1.2027-04
  OXYGEN                   0.0
  WATER                  350.3802
  CO                    1.4082-02
  CO2                      2.2697
  METHANE               2.8324-02
  ETHANE                   5.6082
  ETHENE                   1.7821
TOTAL FLOW:
  LBMOL/HR              4716.3350
  LB/HR                 2.0674+05
  CUFT/HR               1.0150+06
STATE VARIABLES:
  TEMP    F              -28.8264
  PRES    PSIA             20.0000
  VFRAC                     0.9306
  LFRAC                 6.9396-02
  SFRAC                     0.0
ENTHALPY:
  BTU/LBMOL            -4.3507+04
  BTU/LB                -992.5094
  BTU/HR               -2.0520+08
ENTROPY:
  BTU/LBMOL-R            -66.7457
  BTU/LB-R                -1.5226
DENSITY:
  LBMOL/CUFT            4.6465-03
  LB/CUFT                   0.2037
AVG MW                     43.8358

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F              -28.8264
PRES     PSIA             20.0000
HFLMX    BTU/HR        -2.0520+08

S1
--

STREAM ID                 S1
FROM :                    H103
TO   :                    SP101

SUBSTREAM: MIXED
PHASE:                    LIQUID
COMPONENTS: LBMOL/HR
  PROPANE                  0.0
```

```
  PROPENE                0.0
  HYDROGEN               0.0
  OXYGEN                 0.0
  WATER              2.1692+04
  CO                     0.0
  CO2                    0.0
  METHANE                0.0
  ETHANE                 0.0
  ETHENE                 0.0
COMPONENTS: LB/HR
  PROPANE                0.0
  PROPENE                0.0
  HYDROGEN               0.0
  OXYGEN                 0.0
  WATER              3.9079+05
  CO                     0.0
  CO2                    0.0
  METHANE                0.0
  ETHANE                 0.0
  ETHENE                 0.0
TOTAL FLOW:
  LBMOL/HR           2.1692+04
  LB/HR              3.9079+05
  CUFT/HR            6441.9834
STATE VARIABLES:
  TEMP    F           176.0000
  PRES    PSIA         34.8091
  VFRAC                 0.0
  LFRAC                 1.0000
  SFRAC                 0.0
ENTHALPY:
  BTU/LBMOL         -1.2110+05
  BTU/LB            -6722.2463
  BTU/HR            -2.6270+09
ENTROPY:
  BTU/LBMOL-R         -35.9414
  BTU/LB-R             -1.9951
DENSITY:
  LBMOL/CUFT           3.3673
  LB/CUFT             60.6632
AVG MW                18.0153

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F           176.0000
PRES     PSIA         34.8091
HFLMX    BTU/HR    -2.6270+09

S2
--

STREAM ID              S2
FROM :                 R102
TO   :                 H000
CLASS:                 HEAT

STREAM ATTRIBUTES:
HEAT
Q        BTU/HR      6.8346+07
TBEG     F           1094.0000
TEND     F           1094.0000
```

S3
--

STREAM ID		S3
FROM :		SP101
TO :		----
SUBSTREAM: MIXED		
PHASE:		LIQUID
COMPONENTS: LBMOL/HR		
PROPANE		0.0
PROPENE		0.0
HYDROGEN		0.0
OXYGEN		0.0
WATER		2169.2211
CO		0.0
CO2		0.0
METHANE		0.0
ETHANE		0.0
ETHENE		0.0
COMPONENTS: LB/HR		
PROPANE		0.0
PROPENE		0.0
HYDROGEN		0.0
OXYGEN		0.0
WATER		3.9079+04
CO		0.0
CO2		0.0
METHANE		0.0
ETHANE		0.0
ETHENE		0.0
TOTAL FLOW:		
LBMOL/HR		2169.2211
LB/HR		3.9079+04
CUFT/HR		665.6567
STATE VARIABLES:		
TEMP	F	173.8599
PRES	PSIA	34.8091
VFRAC		0.0
LFRAC		1.0000
SFRAC		0.0
ENTHALPY:		
BTU/LBMOL		-1.2110+05
BTU/LB		-6722.2463
BTU/HR		-2.6270+08
ENTROPY:		
BTU/LBMOL-R		-35.9555
BTU/LB-R		-1.9958
DENSITY:		
LBMOL/CUFT		3.2588
LB/CUFT		58.7076
AVG MW		18.0153

MIXED SUBSTREAM PROPERTIES:

*** ALL PHASES ***		
TEMP	F	173.8599
PRES	PSIA	34.8091
HFLMX	BTU/HR	-2.6270+08

S4
--

```
STREAM ID                S4
FROM :                   B6
TO   :                   MX301

SUBSTREAM: MIXED
PHASE:                   LIQUID
COMPONENTS: LBMOL/HR
  PROPANE               2801.5579
  PROPENE                 10.9528
  HYDROGEN                 0.0
  OXYGEN                   0.0
  WATER                   21.6101
  CO                       0.0
  CO2                      0.0
  METHANE                  0.0
  ETHANE                8.4722-28
  ETHENE                   0.0
COMPONENTS: LB/HR
  PROPANE               1.2354+05
  PROPENE                460.8995
  HYDROGEN                 0.0
  OXYGEN                   0.0
  WATER                  389.3114
  CO                       0.0
  CO2                   2.7305-34
  METHANE                  0.0
  ETHANE                2.5476-26
  ETHENE                1.4771-35
TOTAL FLOW:
  LBMOL/HR              2834.1208
  LB/HR                 1.2439+05
  CUFT/HR               4405.1185
STATE VARIABLES:
  TEMP    F              120.1047
  PRES    PSIA            20.0000
  VFRAC                    0.0
  LFRAC                    1.0000
  SFRAC                    0.0
ENTHALPY:
  BTU/LBMOL            -5.0029+04
  BTU/LB               -1139.8679
  BTU/HR               -1.4179+08
ENTROPY:
  BTU/LBMOL-R            -77.3556
  BTU/LB-R                -1.7625
DENSITY:
  LBMOL/CUFT               0.6434
  LB/CUFT                 28.2374
AVG MW                    43.8899

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F              120.1047
PRES     PSIA            20.0000
HFLMX    BTU/HR       -1.4179+08

S6
--

STREAM ID                S6
FROM :                   B2
TO   :                   ----
```

```
SUBSTREAM: MIXED
PHASE:                    VAPOR
COMPONENTS: LBMOL/HR
  PROPANE                   0.0
  PROPENE                   0.0
  HYDROGEN                  0.0
  OXYGEN                2392.5913
  WATER                 5606.5414
  CO                        0.0
  CO2                   1841.4157
  METHANE                   0.0
  ETHANE                    0.0
  ETHENE                    0.0
COMPONENTS: LB/HR
  PROPANE                   0.0
  PROPENE                   0.0
  HYDROGEN                  0.0
  OXYGEN                7.6560+04
  WATER                 1.0100+05
  CO                        0.0
  CO2                   8.1040+04
  METHANE                   0.0
  ETHANE                    0.0
  ETHENE                    0.0
TOTAL FLOW:
  LBMOL/HR              9840.5485
  LB/HR                 2.5860+05
  CUFT/HR               1.1161+07
STATE VARIABLES:
  TEMP    F             1094.0000
  PRES    PSIA            14.7000
  VFRAC                     1.0000
  LFRAC                     0.0
  SFRAC                     0.0
ENTHALPY:
  BTU/LBMOL            -8.1899+04
  BTU/LB               -3116.4657
  BTU/HR               -8.0593+08
ENTROPY:
  BTU/LBMOL-R               5.2575
  BTU/LB-R                  0.2001
DENSITY:
  LBMOL/CUFT           8.8166-04
  LB/CUFT              2.3170-02
AVG MW                    26.2794

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F             1094.0000
PRES     PSIA            14.7000
HFLMX    BTU/HR       -8.0593+08

S7
--

STREAM ID                 S7
FROM :                    ----
TO   :                    B2

SUBSTREAM: MIXED
PHASE:                    VAPOR
```

```
COMPONENTS: LBMOL/HR
  PROPANE                0.0
  PROPENE                0.0
  HYDROGEN               0.0
  OXYGEN              7000.0000
  WATER                  0.0
  CO                     0.0
  CO2                    0.0
  METHANE                0.0
  ETHANE                 0.0
  ETHENE                 0.0
COMPONENTS: LB/HR
  PROPANE                0.0
  PROPENE                0.0
  HYDROGEN               0.0
  OXYGEN              2.2399+05
  WATER                  0.0
  CO                     0.0
  CO2                    0.0
  METHANE                0.0
  ETHANE                 0.0
  ETHENE                 0.0
TOTAL FLOW:
  LBMOL/HR            7000.0000
  LB/HR               2.2399+05
  CUFT/HR             2.7067+06
STATE VARIABLES:
  TEMP    F             70.0000
  PRES    PSIA          14.7000
  VFRAC                  1.0000
  LFRAC                  0.0
  SFRAC                  0.0
ENTHALPY:
  BTU/LBMOL            -49.0505
  BTU/LB                -1.5329
  BTU/HR             -3.4335+05
ENTROPY:
  BTU/LBMOL-R        -9.2547-02
  BTU/LB-R           -2.8922-03
DENSITY:
  LBMOL/CUFT          2.5862-03
  LB/CUFT             8.2754-02
AVG MW                31.9988

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP      F             70.0000
PRES      PSIA          14.7000
HFLMX     BTU/HR     -3.4335+05

S8
--

STREAM ID               S8
FROM :                  B2
TO   :                  B3
CLASS:                  HEAT

STREAM ATTRIBUTES:
HEAT
Q         BTU/HR       7.7441+08
TBEG      F               7.1795
```

```
TEND     F              1094.0000

S9
--

STREAM ID                S9
FROM :                   B3
TO   :                   H101
CLASS:                   HEAT

STREAM ATTRIBUTES:
HEAT
Q        BTU/HR          2.7344+08
TBEG     F                  7.1795
TEND     F              1094.0000

S10
---

STREAM ID                S10
FROM :                   B3
TO   :                   ----
CLASS:                   HEAT

STREAM ATTRIBUTES:
HEAT
Q        BTU/HR          5.3007+07
TBEG     F                  7.1795
TEND     F              1094.0000

S11
---

STREAM ID                S11
FROM :                   B3
TO   :                   ----
CLASS:                   HEAT

STREAM ATTRIBUTES:
HEAT
Q        BTU/HR          2.2034+08
TBEG     F                  7.1795
TEND     F              1094.0000

S12
---

STREAM ID                S12
FROM :                   B3
TO   :                   ----
CLASS:                   HEAT

STREAM ATTRIBUTES:
HEAT
Q        BTU/HR          5.4315+07
TBEG     F                  7.1795
TEND     F              1094.0000

S13
---

STREAM ID                S13
FROM :                   B3
```

```
TO   :                    ----
CLASS:                    HEAT

STREAM ATTRIBUTES:
HEAT
Q        BTU/HR        1.1345+07
TBEG     F               7.1795
TEND     F             1094.0000

S14
---

STREAM ID                 S14
FROM :                    B3
TO   :                    ----
CLASS:                    HEAT

STREAM ATTRIBUTES:
HEAT
Q        BTU/HR        1.6196+08
TBEG     F               7.1795
TEND     F             1094.0000

S15
---

STREAM ID                 S15
FROM :                    HX101
TO   :                    R101

SUBSTREAM: MIXED
PHASE:                    VAPOR
COMPONENTS: LBMOL/HR
  PROPANE               9223.3119
  PROPENE                356.5092
  HYDROGEN              5.9663-05
  OXYGEN                  0.0
  WATER                 2.1416+04
  CO                    5.0273-04
  CO2                   5.1573-02
  METHANE               1.7656-03
  ETHANE                  0.1865
  ETHENE                6.3526-02
COMPONENTS: LB/HR
  PROPANE               4.0672+05
  PROPENE               1.5002+04
  HYDROGEN              1.2027-04
  OXYGEN                  0.0
  WATER                 3.8582+05
  CO                    1.4082-02
  CO2                     2.2697
  METHANE               2.8324-02
  ETHANE                  5.6082
  ETHENE                  1.7821
TOTAL FLOW:
  LBMOL/HR              3.0996+04
  LB/HR                 8.0755+05
  CUFT/HR               7.1265+06
STATE VARIABLES:
  TEMP    F             1094.0000
  PRES    PSIA            72.5189
  VFRAC                   1.0000
  LFRAC                   0.0
```

```
  SFRAC                    0.0
ENTHALPY:
  BTU/LBMOL           -6.9874+04
  BTU/LB              -2681.9833
  BTU/HR              -2.1658+09
ENTROPY:
  BTU/LBMOL-R          -13.4731
  BTU/LB-R              -0.5171
DENSITY:
  LBMOL/CUFT          4.3495-03
  LB/CUFT               0.1133
AVG MW                 26.0529

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F            1094.0000
PRES     PSIA           72.5189
HFLMX    BTU/HR      -2.1658+09

S16
---

STREAM ID               S16
FROM :                  ----
TO   :                  H101
CLASS:                  HEAT

STREAM ATTRIBUTES:
HEAT
Q        BTU/HR        1.6500+08

S101
----

STREAM ID               S101
FROM :                  ----
TO   :                  MX101

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: LBMOL/HR
  PROPANE                0.0
  PROPENE                0.0
  HYDROGEN               0.0
  OXYGEN                 0.0
  WATER               1873.9292
  CO                     0.0
  CO2                    0.0
  METHANE                0.0
  ETHANE                 0.0
  ETHENE                 0.0
COMPONENTS: LB/HR
  PROPANE                0.0
  PROPENE                0.0
  HYDROGEN               0.0
  OXYGEN                 0.0
  WATER               3.3759+04
  CO                     0.0
  CO2                    0.0
  METHANE                0.0
  ETHANE                 0.0
  ETHENE                 0.0
```

```
TOTAL FLOW:
  LBMOL/HR            1873.9292
  LB/HR               3.3759+04
  CUFT/HR              544.0608
STATE VARIABLES:
  TEMP    F             77.0000
  PRES    PSIA          72.5189
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  BTU/LBMOL          -1.2287+05
  BTU/LB             -6820.4298
  BTU/HR             -2.3025+08
ENTROPY:
  BTU/LBMOL-R          -38.9652
  BTU/LB-R              -2.1629
DENSITY:
  LBMOL/CUFT             3.4443
  LB/CUFT               62.0507
AVG MW                  18.0153

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP      F             77.0000
PRES      PSIA          72.5189
HFLMX     BTU/HR     -2.3025+08

S102
----

STREAM ID               S102
FROM :                  MX101
TO   :                  H101

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: LBMOL/HR
  PROPANE                0.0
  PROPENE                0.0
  HYDROGEN               0.0
  OXYGEN                 0.0
  WATER               2.1397+04
  CO                     0.0
  CO2                    0.0
  METHANE                0.0
  ETHANE                 0.0
  ETHENE                 0.0
COMPONENTS: LB/HR
  PROPANE                0.0
  PROPENE                0.0
  HYDROGEN               0.0
  OXYGEN                 0.0
  WATER               3.8547+05
  CO                     0.0
  CO2                    0.0
  METHANE                0.0
  ETHANE                 0.0
  ETHENE                 0.0
TOTAL FLOW:
  LBMOL/HR            2.1397+04
  LB/HR               3.8547+05
```

```
  CUFT/HR              6533.9742
STATE VARIABLES:
  TEMP    F             165.7822
  PRES    PSIA           72.5189
  VFRAC                   0.0
  LFRAC                   1.0000
  SFRAC                   0.0
ENTHALPY:
  BTU/LBMOL          -1.2126+05
  BTU/LB             -6730.7001
  BTU/HR             -2.5945+09
ENTROPY:
  BTU/LBMOL-R          -36.1949
  BTU/LB-R              -2.0091
DENSITY:
  LBMOL/CUFT             3.2747
  LB/CUFT               58.9950
AVG MW                  18.0153

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F             165.7822
PRES     PSIA           72.5189
HFLMX    BTU/HR     -2.5945+09

S103
----

STREAM ID               S103
FROM :                  ----
TO   :                  MX102

SUBSTREAM: MIXED
PHASE:                  VAPOR
COMPONENTS: LBMOL/HR
  PROPANE              4883.2391
  PROPENE                 0.0
  HYDROGEN                0.0
  OXYGEN                  0.0
  WATER                   0.0
  CO                      0.0
  CO2                     0.0
  METHANE                 0.0
  ETHANE                  0.0
  ETHENE                  0.0
COMPONENTS: LB/HR
  PROPANE            2.1533+05
  PROPENE                 0.0
  HYDROGEN                0.0
  OXYGEN                  0.0
  WATER                   0.0
  CO                      0.0
  CO2                     0.0
  METHANE                 0.0
  ETHANE                  0.0
  ETHENE                  0.0
TOTAL FLOW:
  LBMOL/HR             4883.2391
  LB/HR              2.1533+05
  CUFT/HR            3.8781+05
STATE VARIABLES:
  TEMP    F              77.0000
```

```
  PRES    PSIA            72.5189
  VFRAC                    1.0000
  LFRAC                    0.0
  SFRAC                    0.0
ENTHALPY:
  BTU/LBMOL           -4.5004+04
  BTU/LB              -1020.5862
  BTU/HR              -2.1977+08
ENTROPY:
  BTU/LBMOL-R           -67.4897
  BTU/LB-R               -1.5305
DENSITY:
  LBMOL/CUFT          1.2592-02
  LB/CUFT                0.5553
AVG MW                  44.0965

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP      F             77.0000
PRES      PSIA          72.5189
HFLMX     BTU/HR     -2.1977+08

S104
----

STREAM ID               S104
FROM :                  H101
TO   :                  MX102

SUBSTREAM: MIXED
PHASE:                  VAPOR
COMPONENTS: LBMOL/HR
  PROPANE                0.0
  PROPENE                0.0
  HYDROGEN               0.0
  OXYGEN                 0.0
  WATER               2.1397+04
  CO                     0.0
  CO2                    0.0
  METHANE                0.0
  ETHANE                 0.0
  ETHENE                 0.0
COMPONENTS: LB/HR
  PROPANE                0.0
  PROPENE                0.0
  HYDROGEN               0.0
  OXYGEN                 0.0
  WATER               3.8547+05
  CO                     0.0
  CO2                    0.0
  METHANE                0.0
  ETHANE                 0.0
  ETHENE                 0.0
TOTAL FLOW:
  LBMOL/HR            2.1397+04
  LB/HR               3.8547+05
  CUFT/HR             2.9332+06
STATE VARIABLES:
  TEMP    F            466.6963
  PRES    PSIA          72.5189
  VFRAC                  1.0000
  LFRAC                  0.0
```

```
  SFRAC                    0.0
ENTHALPY:
  BTU/LBMOL          -1.0076+05
  BTU/LB             -5593.2896
  BTU/HR             -2.1561+09
ENTROPY:
  BTU/LBMOL-R           -9.3117
  BTU/LB-R              -0.5169
DENSITY:
  LBMOL/CUFT         7.2948-03
  LB/CUFT               0.1314
AVG MW                 18.0153

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F             466.6963
PRES     PSIA           72.5189
HFLMX    BTU/HR     -2.1561+09

S105
----

STREAM ID                S105
FROM :                   MX102
TO   :                   HX101


MAX CONV. ERROR:       1.3573-06
SUBSTREAM: MIXED
PHASE:                   VAPOR
COMPONENTS: LBMOL/HR
  PROPANE              9223.3119
  PROPENE               356.5092
  HYDROGEN             5.9663-05
  OXYGEN                  0.0
  WATER                2.1416+04
  CO                   5.0273-04
  CO2                  5.1573-02
  METHANE              1.7656-03
  ETHANE                  0.1865
  ETHENE               6.3526-02
COMPONENTS: LB/HR
  PROPANE              4.0672+05
  PROPENE              1.5002+04
  HYDROGEN             1.2027-04
  OXYGEN                  0.0
  WATER                3.8582+05
  CO                   1.4082-02
  CO2                     2.2697
  METHANE              2.8324-02
  ETHANE                  5.6082
  ETHENE                  1.7821
TOTAL FLOW:
  LBMOL/HR             3.0996+04
  LB/HR                8.0755+05
  CUFT/HR              3.4307+06
STATE VARIABLES:
  TEMP    F             288.2717
  PRES    PSIA           72.5189
  VFRAC                   1.0000
  LFRAC                   0.0
  SFRAC                   0.0
```

```
ENTHALPY:
  BTU/LBMOL          -8.2621+04
  BTU/LB             -3171.2595
  BTU/HR             -2.5609+09
ENTROPY:
  BTU/LBMOL-R          -24.7911
  BTU/LB-R              -0.9516
DENSITY:
  LBMOL/CUFT         9.0350-03
  LB/CUFT               0.2354
AVG MW                 26.0529

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F            288.2717
PRES     PSIA          72.5189
HFLMX    BTU/HR     -2.5609+09

S108
----

STREAM ID              S108
FROM :                 R101
TO   :                 R102

SUBSTREAM: MIXED
PHASE:                 VAPOR
COMPONENTS: LBMOL/HR
  PROPANE            6323.7425
  PROPENE            3243.4059
  HYDROGEN           2883.0758
  OXYGEN                0.0
  WATER              2.1416+04
  CO                 5.0273-04
  CO2                5.1573-02
  METHANE              12.6746
  ETHANE                4.0074
  ETHENE                8.9154
COMPONENTS: LB/HR
  PROPANE            2.7886+05
  PROPENE            1.3648+05
  HYDROGEN           5811.9348
  OXYGEN                0.0
  WATER              3.8582+05
  CO                 1.4082-02
  CO2                   2.2697
  METHANE             203.3355
  ETHANE              120.5015
  ETHENE              250.1119
TOTAL FLOW:
  LBMOL/HR           3.3892+04
  LB/HR              8.0755+05
  CUFT/HR            7.7409+06
STATE VARIABLES:
  TEMP   F           1094.0000
  PRES   PSIA          73.0000
  VFRAC                 1.0000
  LFRAC                 0.0
  SFRAC                 0.0
ENTHALPY:
  BTU/LBMOL          -5.9125+04
  BTU/LB             -2481.4258
```

```
  BTU/HR             -2.0039+09
ENTROPY:
  BTU/LBMOL-R          -8.9101
  BTU/LB-R             -0.3740
DENSITY:
  LBMOL/CUFT         4.3783-03
  LB/CUFT              0.1043
AVG MW                23.8270

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F           1094.0000
PRES     PSIA          73.0000
HFLMX    BTU/HR     -2.0039+09

S109
----

STREAM ID              S109
FROM :                 ----
TO   :                 R102

SUBSTREAM: MIXED
PHASE:                 VAPOR
COMPONENTS: LBMOL/HR
  PROPANE               0.0
  PROPENE               0.0
  HYDROGEN              0.0
  OXYGEN              750.0000
  WATER                 0.0
  CO                    0.0
  CO2                   0.0
  METHANE               0.0
  ETHANE                0.0
  ETHENE                0.0
COMPONENTS: LB/HR
  PROPANE               0.0
  PROPENE               0.0
  HYDROGEN              0.0
  OXYGEN             2.3999+04
  WATER                 0.0
  CO                    0.0
  CO2                   0.0
  METHANE               0.0
  ETHANE                0.0
  ETHENE                0.0
TOTAL FLOW:
  LBMOL/HR            750.0000
  LB/HR              2.3999+04
  CUFT/HR            1.7130+05
STATE VARIABLES:
  TEMP   F           1094.0000
  PRES   PSIA          73.0000
  VFRAC                 1.0000
  LFRAC                 0.0
  SFRAC                 0.0
ENTHALPY:
  BTU/LBMOL          7727.2183
  BTU/LB              241.4846
  BTU/HR             5.7954+06
ENTROPY:
  BTU/LBMOL-R           4.7795
```

```
  BTU/LB-R                0.1494
DENSITY:
  LBMOL/CUFT           4.3783-03
  LB/CUFT                 0.1401
AVG MW                   31.9988

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP      F             1094.0000
PRES      PSIA            73.0000
HFLMX     BTU/HR       5.7954+06

S110
----

STREAM ID                 S110
FROM :                    H000
TO   :                    HX101


MAX CONV. ERROR:         1.4425-02
SUBSTREAM: MIXED
PHASE:                    VAPOR
COMPONENTS: LBMOL/HR
  PROPANE                4844.6952
  PROPENE                4633.5591
  HYDROGEN               3322.1622
  OXYGEN                    0.0
  WATER                  2.2301+04
  CO                       58.3703
  CO2                     117.7321
  METHANE                  18.0742
  ETHANE                    8.2998
  ETHENE                   10.0203
COMPONENTS: LB/HR
  PROPANE                2.1363+05
  PROPENE                1.9498+05
  HYDROGEN               6697.0804
  OXYGEN                    0.0
  WATER                  4.0176+05
  CO                     1634.9760
  CO2                    5181.3675
  METHANE                 289.9595
  ETHANE                  249.5730
  ETHENE                  281.1069
TOTAL FLOW:
  LBMOL/HR               3.5314+04
  LB/HR                  8.2471+05
  CUFT/HR                1.2076+07
STATE VARIABLES:
  TEMP    F              1210.7455
  PRES    PSIA             52.5000
  VFRAC                     1.0000
  LFRAC                     0.0
  SFRAC                     0.0
ENTHALPY:
  BTU/LBMOL             -5.5737+04
  BTU/LB                -2386.6621
  BTU/HR                -1.9683+09
ENTROPY:
  BTU/LBMOL-R              -5.3986
  BTU/LB-R                 -0.2312
```

```
DENSITY:
  LBMOL/CUFT          2.9243-03
  LB/CUFT             6.8294-02
AVG MW                  23.3537

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F            1210.7455
PRES     PSIA           52.5000
HFLMX    BTU/HR      -1.9688+09

S111
----

STREAM ID               S111
FROM :                  HX101
TO   :                  T101

SUBSTREAM: MIXED
PHASE:                  VAPOR
COMPONENTS: LBMOL/HR
  PROPANE              4844.6952
  PROPENE              4633.5591
  HYDROGEN             3322.1622
  OXYGEN                  0.0
  WATER                2.2301+04
  CO                     58.3703
  CO2                   117.7321
  METHANE                18.0742
  ETHANE                  8.2998
  ETHENE                 10.0203
COMPONENTS: LB/HR
  PROPANE              2.1363+05
  PROPENE              1.9498+05
  HYDROGEN             6697.0804
  OXYGEN                  0.0
  WATER                4.0176+05
  CO                   1634.9760
  CO2                  5181.3675
  METHANE               289.9595
  ETHANE                249.5730
  ETHENE                281.1069
TOTAL FLOW:
  LBMOL/HR             3.5314+04
  LB/HR                8.2471+05
  CUFT/HR              6.6444+06
STATE VARIABLES:
  TEMP   F              460.8083
  PRES   PSIA            52.5000
  VFRAC                   1.0000
  LFRAC                   0.0
  SFRAC                   0.0
ENTHALPY:
  BTU/LBMOL           -6.6926+04
  BTU/LB              -2865.7580
  BTU/HR              -2.3634+09
ENTROPY:
  BTU/LBMOL-R           -14.1825
  BTU/LB-R               -0.6073
DENSITY:
  LBMOL/CUFT          5.3148-03
  LB/CUFT                 0.1241
```

```
AVG MW                    23.3537

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP      F              460.8083
PRES      PSIA            52.5000
HFLMX     BTU/HR       -2.3634+09

S112
----

STREAM ID                  S112
FROM :                     T101
TO   :                     H103

SUBSTREAM: MIXED
PHASE:                     VAPOR
COMPONENTS: LBMOL/HR
  PROPANE                4844.6952
  PROPENE                4633.5591
  HYDROGEN               3322.1622
  OXYGEN                    0.0
  WATER                  2.2301+04
  CO                       58.3703
  CO2                     117.7321
  METHANE                  18.0742
  ETHANE                    8.2998
  ETHENE                   10.0203
COMPONENTS: LB/HR
  PROPANE                2.1363+05
  PROPENE                1.9498+05
  HYDROGEN               6697.0804
  OXYGEN                    0.0
  WATER                  4.0176+05
  CO                     1634.9760
  CO2                    5181.3675
  METHANE                 289.9595
  ETHANE                  249.5730
  ETHENE                  281.1069
TOTAL FLOW:
  LBMOL/HR               3.5314+04
  LB/HR                  8.2471+05
  CUFT/HR                9.5716+06
STATE VARIABLES:
  TEMP    F               419.5034
  PRES    PSIA             34.8091
  VFRAC                     1.0000
  LFRAC                     0.0
  SFRAC                     0.0
ENTHALPY:
  BTU/LBMOL             -6.7450+04
  BTU/LB                -2888.1876
  BTU/HR                -2.3819+09
ENTROPY:
  BTU/LBMOL-R             -13.9486
  BTU/LB-R                 -0.5973
DENSITY:
  LBMOL/CUFT             3.6894-03
  LB/CUFT                8.6162-02
AVG MW                    23.3537

MIXED    SUBSTREAM PROPERTIES:
```

```
***  ALL PHASES   ***
TEMP     F             419.5034
PRES     PSIA           34.8091
HFLMX    BTU/HR      -2.3819+09

S114
----

STREAM ID               S114
FROM :                  H103
TO   :                  AD201

SUBSTREAM: MIXED
PHASE:                  VAPOR
COMPONENTS: LBMOL/HR
  PROPANE              4844.6952
  PROPENE              4633.5591
  HYDROGEN             3322.1622
  OXYGEN                  0.0
  WATER                 608.7342
  CO                     58.3703
  CO2                   117.7321
  METHANE                18.0742
  ETHANE                  8.2998
  ETHENE                 10.0203
COMPONENTS: LB/HR
  PROPANE              2.1363+05
  PROPENE              1.9498+05
  HYDROGEN             6697.0804
  OXYGEN                  0.0
  WATER                1.0967+04
  CO                   1634.9760
  CO2                  5181.3675
  METHANE               289.9595
  ETHANE                249.5730
  ETHENE                281.1069
TOTAL FLOW:
  LBMOL/HR             1.3622+04
  LB/HR                4.3392+05
  CUFT/HR              2.6695+06
STATE VARIABLES:
  TEMP   F              176.0000
  PRES   PSIA            34.8091
  VFRAC                   1.0000
  LFRAC                   0.0
  SFRAC                   0.0
ENTHALPY:
  BTU/LBMOL           -1.7973+04
  BTU/LB               -564.1984
  BTU/HR              -2.4482+08
ENTROPY:
  BTU/LBMOL-R           -31.5497
  BTU/LB-R               -0.9904
DENSITY:
  LBMOL/CUFT          5.1027-03
  LB/CUFT                0.1625
AVG MW                  31.8550

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F             176.0000
```

```
PRES     PSIA           34.8091
HFLMX    BTU/HR      -2.4482+08

S116
----

STREAM ID                S116
FROM :                   P101
TO   :                   MX101

SUBSTREAM: MIXED
PHASE:                   LIQUID
COMPONENTS: LBMOL/HR
  PROPANE                 0.0
  PROPENE                 0.0
  HYDROGEN                0.0
  OXYGEN                  0.0
  WATER                1.9523+04
  CO                      0.0
  CO2                     0.0
  METHANE                 0.0
  ETHANE                  0.0
  ETHENE                  0.0
COMPONENTS: LB/HR
  PROPANE                 0.0
  PROPENE                 0.0
  HYDROGEN                0.0
  OXYGEN                  0.0
  WATER                3.5171+05
  CO                      0.0
  CO2                     0.0
  METHANE                 0.0
  ETHANE                  0.0
  ETHENE                  0.0
TOTAL FLOW:
  LBMOL/HR             1.9523+04
  LB/HR                3.5171+05
  CUFT/HR              5991.4609
STATE VARIABLES:
  TEMP    F             174.0112
  PRES    PSIA           72.5189
  VFRAC                   0.0
  LFRAC                   1.0000
  SFRAC                   0.0
ENTHALPY:
  BTU/LBMOL           -1.2110+05
  BTU/LB              -6722.0873
  BTU/HR              -2.3642+09
ENTROPY:
  BTU/LBMOL-R           -35.9511
  BTU/LB-R               -1.9956
DENSITY:
  LBMOL/CUFT             3.2585
  LB/CUFT               58.7022
AVG MW                  18.0153

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F             174.0112
PRES     PSIA           72.5189
HFLMX    BTU/HR      -2.3642+09
```

S202

STREAM ID		S202
FROM :		AD201
TO :		----
SUBSTREAM: MIXED		
PHASE:		LIQUID
COMPONENTS:	LBMOL/HR	
PROPANE		0.0
PROPENE		0.0
HYDROGEN		0.0
OXYGEN		0.0
WATER		578.2975
CO		0.0
CO2		0.0
METHANE		0.1807
ETHANE		8.2998-02
ETHENE		0.0
COMPONENTS:	LB/HR	
PROPANE		0.0
PROPENE		0.0
HYDROGEN		0.0
OXYGEN		0.0
WATER		1.0418+04
CO		0.0
CO2		0.0
METHANE		2.8996
ETHANE		2.4957
ETHENE		0.0
TOTAL FLOW:		
LBMOL/HR		578.5612
LB/HR		1.0424+04
CUFT/HR		177.9018
STATE VARIABLES:		
TEMP	F	176.0000
PRES	PSIA	34.8091
VFRAC		0.0
LFRAC		1.0000
SFRAC		0.0
ENTHALPY:		
BTU/LBMOL		-1.2102+05
BTU/LB		-6717.3352
BTU/HR		-7.0019+07
ENTROPY:		
BTU/LBMOL-R		-35.8847
BTU/LB-R		-1.9918
DENSITY:		
LBMOL/CUFT		3.2521
LB/CUFT		58.5918
AVG MW		18.0164

MIXED SUBSTREAM PROPERTIES:

*** ALL PHASES ***		
TEMP	F	176.0000
PRES	PSIA	34.8091
HFLMX	BTU/HR	-7.0019+07

S203

STREAM ID		S203
FROM :		AD201
TO :		MEA201
SUBSTREAM: MIXED		
PHASE:		VAPOR
COMPONENTS: LBMOL/HR		
PROPANE		4844.6952
PROPENE		4633.5591
HYDROGEN		3322.1622
OXYGEN		0.0
WATER		30.4367
CO		58.3703
CO2		117.7321
METHANE		17.8934
ETHANE		8.2168
ETHENE		10.0203
COMPONENTS: LB/HR		
PROPANE		2.1363+05
PROPENE		1.9498+05
HYDROGEN		6697.0804
OXYGEN		0.0
WATER		548.3259
CO		1634.9760
CO2		5181.3675
METHANE		287.0599
ETHANE		247.0773
ETHENE		281.1069
TOTAL FLOW:		
LBMOL/HR		1.3043+04
LB/HR		4.2349+05
CUFT/HR		2.5561+06
STATE VARIABLES:		
TEMP	F	176.0000
PRES	PSIA	34.8091
VFRAC		1.0000
LFRAC		0.0
SFRAC		0.0
ENTHALPY:		
BTU/LBMOL		-1.4195+04
BTU/LB		-437.1884
BTU/HR		-1.8515+08
ENTROPY:		
BTU/LBMOL-R		-32.8089
BTU/LB-R		-1.0105
DENSITY:		
LBMOL/CUFT		5.1027-03
LB/CUFT		0.1657
AVG MW		32.4689

MIXED SUBSTREAM PROPERTIES:

*** ALL PHASES ***		
TEMP	F	176.0000
PRES	PSIA	34.8091
HFLMX	BTU/HR	-1.8515+08

S204

STREAM ID		S204
FROM :		MEA201
TO :		----

```
SUBSTREAM: MIXED
PHASE:                    VAPOR
COMPONENTS: LBMOL/HR
  PROPANE                   0.0
  PROPENE                   0.0
  HYDROGEN                  3.3222
  OXYGEN                    0.0
  WATER                     8.8266
  CO                        0.0
  CO2                     110.6682
  METHANE                   0.0
  ETHANE                    0.0
  ETHENE                    0.0
COMPONENTS: LB/HR
  PROPANE                   0.0
  PROPENE                   0.0
  HYDROGEN                  6.6971
  OXYGEN                    0.0
  WATER                   159.0145
  CO                        0.0
  CO2                    4870.4854
  METHANE                   0.0
  ETHANE                    0.0
  ETHENE                    0.0
TOTAL FLOW:
  LBMOL/HR                122.8170
  LB/HR                  5036.1970
  CUFT/HR                2.4069+04
STATE VARIABLES:
  TEMP    F               176.0000
  PRES    PSIA             34.8091
  VFRAC                     1.0000
  LFRAC                     0.0
  SFRAC                     0.0
ENTHALPY:
  BTU/LBMOL             -1.5902+05
  BTU/LB                -3877.9452
  BTU/HR                -1.9530+07
ENTROPY:
  BTU/LBMOL-R               0.4358
  BTU/LB-R               1.0628-02
DENSITY:
  LBMOL/CUFT             5.1027-03
  LB/CUFT                   0.2092
AVG MW                     41.0057

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F               176.0000
PRES     PSIA             34.8091
HFLMX    BTU/HR        -1.9530+07

S205
----

STREAM ID                  S205
FROM :                     MEA201
TO   :                     C201

SUBSTREAM: MIXED
PHASE:                     VAPOR
```

```
COMPONENTS: LBMOL/HR
  PROPANE              4844.6952
  PROPENE              4633.5591
  HYDROGEN             3318.8401
  OXYGEN                  0.0
  WATER                  21.6101
  CO                     58.3703
  CO2                     7.0639
  METHANE                17.8934
  ETHANE                  8.2168
  ETHENE                 10.0203
COMPONENTS: LB/HR
  PROPANE              2.1363+05
  PROPENE              1.9498+05
  HYDROGEN             6690.3833
  OXYGEN                  0.0
  WATER                 389.3114
  CO                   1634.9760
  CO2                   310.8820
  METHANE               287.0599
  ETHANE                247.0773
  ETHENE                281.1069
TOTAL FLOW:
  LBMOL/HR             1.2920+04
  LB/HR                4.1846+05
  CUFT/HR              2.5320+06
STATE VARIABLES:
  TEMP    F             176.0000
  PRES    PSIA           34.8091
  VFRAC                   1.0000
  LFRAC                   0.0
  SFRAC                   0.0
ENTHALPY:
  BTU/LBMOL           -1.2818+04
  BTU/LB               -395.7785
  BTU/HR              -1.6562+08
ENTROPY:
  BTU/LBMOL-R           -33.2208
  BTU/LB-R               -1.0257
DENSITY:
  LBMOL/CUFT           5.1027-03
  LB/CUFT                 0.1653
AVG MW                   32.3877

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F             176.0000
PRES     PSIA           34.8091
HFLMX    BTU/HR      -1.6562+08

S206
----

STREAM ID                S206
FROM :                   C201
TO   :                   C202

SUBSTREAM: MIXED
PHASE:                   VAPOR
COMPONENTS: LBMOL/HR
  PROPANE              4844.6952
  PROPENE              4633.5591
```

```
  HYDROGEN            3318.8401
  OXYGEN                 0.0
  WATER                 21.6101
  CO                    58.3703
  CO2                    7.0639
  METHANE               17.8934
  ETHANE                 8.2168
  ETHENE                10.0203
COMPONENTS: LB/HR
  PROPANE             2.1363+05
  PROPENE             1.9498+05
  HYDROGEN            6690.3833
  OXYGEN                 0.0
  WATER                389.3114
  CO                  1634.9760
  CO2                  310.8820
  METHANE              287.0599
  ETHANE               247.0773
  ETHENE               281.1069
TOTAL FLOW:
  LBMOL/HR            1.2920+04
  LB/HR               4.1846+05
  CUFT/HR             1.0453+06
STATE VARIABLES:
  TEMP    F            294.1946
  PRES    PSIA         100.0000
  VFRAC                  1.0000
  LFRAC                  0.0
  SFRAC                  0.0
ENTHALPY:
  BTU/LBMOL          -1.0843+04
  BTU/LB              -334.7887
  BTU/HR             -1.4010+08
ENTROPY:
  BTU/LBMOL-R          -32.4714
  BTU/LB-R              -1.0026
DENSITY:
  LBMOL/CUFT          1.2361-02
  LB/CUFT                0.4003
AVG MW                  32.3877

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F            294.1946
PRES     PSIA         100.0000
HFLMX    BTU/HR     -1.4010+08

S207
----

STREAM ID               S207
FROM :                  C202
TO   :                  DC201

SUBSTREAM: MIXED
PHASE:                  VAPOR
COMPONENTS: LBMOL/HR
  PROPANE             4844.6952
  PROPENE             4633.5591
  HYDROGEN            3318.8401
  OXYGEN                 0.0
  WATER                 21.6101
```

```
  CO                      58.3703
  CO2                      7.0639
  METHANE                 17.8934
  ETHANE                   8.2168
  ETHENE                  10.0203
COMPONENTS: LB/HR
  PROPANE               2.1363+05
  PROPENE               1.9498+05
  HYDROGEN              6690.3833
  OXYGEN                   0.0
  WATER                  389.3114
  CO                    1634.9760
  CO2                    310.8820
  METHANE                287.0599
  ETHANE                 247.0773
  ETHENE                 281.1069
TOTAL FLOW:
  LBMOL/HR              1.2920+04
  LB/HR                 4.1846+05
  CUFT/HR               4.0814+05
STATE VARIABLES:
  TEMP    F              423.4221
  PRES    PSIA           300.0000
  VFRAC                    1.0000
  LFRAC                    0.0
  SFRAC                    0.0
ENTHALPY:
  BTU/LBMOL            -8416.4966
  BTU/LB                -259.8669
  BTU/HR               -1.0874+08
ENTROPY:
  BTU/LBMOL-R            -31.6865
  BTU/LB-R                -0.9783
DENSITY:
  LBMOL/CUFT           3.1656-02
  LB/CUFT                  1.0253
AVG MW                    32.3877

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F              423.4221
PRES     PSIA           300.0000
HFLMX    BTU/HR       -1.0874+08

S301
----

STREAM ID                 S301
FROM :                    DC201
TO   :                    DC301

SUBSTREAM: MIXED
PHASE:                    LIQUID
COMPONENTS: LBMOL/HR
  PROPANE               4843.3406
  PROPENE               4582.7003
  HYDROGEN              6.6292-05
  OXYGEN                   0.0
  WATER                   21.6101
  CO                    5.5859-04
  CO2                   5.7303-02
  METHANE               1.9617-03
```

```
  ETHANE                 0.2072
  ETHENE               7.0584-02
COMPONENTS: LB/HR
  PROPANE              2.1357+05
  PROPENE              1.9284+05
  HYDROGEN             1.3364-04
  OXYGEN                 0.0
  WATER                 389.3114
  CO                   1.5646-02
  CO2                    2.5219
  METHANE              3.1472-02
  ETHANE                 6.2314
  ETHENE                 1.9802
TOTAL FLOW:
  LBMOL/HR             9447.9886
  LB/HR                4.0682+05
  CUFT/HR              1.4441+04
STATE VARIABLES:
  TEMP    F             124.8463
  PRES    PSIA          281.9800
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  BTU/LBMOL           -2.3480+04
  BTU/LB               -545.3003
  BTU/HR              -2.2184+08
ENTROPY:
  BTU/LBMOL-R           -61.3611
  BTU/LB-R               -1.4251
DENSITY:
  LBMOL/CUFT             0.6543
  LB/CUFT               28.1711
AVG MW                  43.0586

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F             124.8463
PRES     PSIA          281.9800
HFLMX    BTU/HR      -2.2184+08

S302
----

STREAM ID                S302
FROM :                   DC301
TO   :                   B6

SUBSTREAM: MIXED
PHASE:                   LIQUID
COMPONENTS: LBMOL/HR
  PROPANE              2801.5579
  PROPENE                10.9528
  HYDROGEN                0.0
  OXYGEN                  0.0
  WATER                  21.6101
  CO                      0.0
  CO2                     0.0
  METHANE                 0.0
  ETHANE                8.4722-28
  ETHENE                  0.0
COMPONENTS: LB/HR
```

```
  PROPANE              1.2354+05
  PROPENE               460.8995
  HYDROGEN                0.0
  OXYGEN                  0.0
  WATER                 389.3114
  CO                      0.0
  CO2                  2.7305-34
  METHANE                 0.0
  ETHANE               2.5476-26
  ETHENE               1.4771-35
TOTAL FLOW:
  LBMOL/HR             2834.1208
  LB/HR                1.2439+05
  CUFT/HR              4416.5585
STATE VARIABLES:
  TEMP    F             121.1944
  PRES    PSIA          244.6800
  VFRAC                   0.0
  LFRAC                   1.0000
  SFRAC                   0.0
ENTHALPY:
  BTU/LBMOL           -4.9982+04
  BTU/LB              -1138.8023
  BTU/HR              -1.4165+08
ENTROPY:
  BTU/LBMOL-R           -77.2836
  BTU/LB-R               -1.7609
DENSITY:
  LBMOL/CUFT             0.6417
  LB/CUFT               28.1643
AVG MW                  43.8899

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F             121.1944
PRES     PSIA          244.6800
HFLMX    BTU/HR      -1.4165+08

S303
----

STREAM ID               S303
FROM :                  DC301
TO   :                  P301

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: LBMOL/HR
  PROPANE              2041.7827
  PROPENE              4571.7475
  HYDROGEN             6.6292-05
  OXYGEN                  0.0
  WATER                   0.0
  CO                   5.5859-04
  CO2                  5.7303-02
  METHANE              1.9617-03
  ETHANE                  0.2072
  ETHENE               7.0584-02
COMPONENTS: LB/HR
  PROPANE              9.0036+04
  PROPENE              1.9238+05
  HYDROGEN             1.3364-04
```

```
  OXYGEN                   0.0
  WATER                    0.0
  CO                   1.5646-02
  CO2                      2.5219
  METHANE              3.1472-02
  ETHANE                   6.2314
  ETHENE                   1.9802
TOTAL FLOW:
  LBMOL/HR             6613.8679
  LB/HR                2.8243+05
  CUFT/HR              9476.0785
STATE VARIABLES:
  TEMP    F             102.9747
  PRES    PSIA          225.0000
  VFRAC                    0.0
  LFRAC                    1.0000
  SFRAC                    0.0
ENTHALPY:
  BTU/LBMOL           -1.3106+04
  BTU/LB               -306.9180
  BTU/HR              -8.6682+07
ENTROPY:
  BTU/LBMOL-R           -56.7877
  BTU/LB-R               -1.3298
DENSITY:
  LBMOL/CUFT             0.6980
  LB/CUFT               29.8043
AVG MW                  42.7024

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F             102.9747
PRES     PSIA          225.0000
HFLMX    BTU/HR      -8.6682+07

S304
----

STREAM ID                S304
FROM :                   P301
TO   :                   HX301

SUBSTREAM: MIXED
PHASE:                   LIQUID
COMPONENTS: LBMOL/HR
  PROPANE              2041.7827
  PROPENE              4571.7475
  HYDROGEN             6.6292-05
  OXYGEN                   0.0
  WATER                    0.0
  CO                   5.5859-04
  CO2                  5.7303-02
  METHANE              1.9617-03
  ETHANE                   0.2072
  ETHENE               7.0584-02
COMPONENTS: LB/HR
  PROPANE              9.0036+04
  PROPENE              1.9238+05
  HYDROGEN             1.3364-04
  OXYGEN                   0.0
  WATER                    0.0
  CO                   1.5646-02
```

```
  CO2                      2.5219
  METHANE              3.1472-02
  ETHANE                   6.2314
  ETHENE                   1.9802
TOTAL FLOW:
  LBMOL/HR             6613.8679
  LB/HR                2.8243+05
  CUFT/HR              9538.6338
STATE VARIABLES:
  TEMP    F             105.9465
  PRES    PSIA          575.0000
  VFRAC                    0.0
  LFRAC                    1.0000
  SFRAC                    0.0
ENTHALPY:
  BTU/LBMOL           -1.2988+04
  BTU/LB               -304.1413
  BTU/HR              -8.5898+07
ENTROPY:
  BTU/LBMOL-R           -56.5991
  BTU/LB-R               -1.3254
DENSITY:
  LBMOL/CUFT             0.6934
  LB/CUFT               29.6089
AVG MW                  42.7024

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F             105.9465
PRES     PSIA          575.0000
HFLMX    BTU/HR      -8.5898+07

S305
----

STREAM ID                S305
FROM :                   HX301
TO   :                   H301

SUBSTREAM: MIXED
PHASE:                   LIQUID
COMPONENTS: LBMOL/HR
  PROPANE              2041.7827
  PROPENE              4571.7475
  HYDROGEN             6.6292-05
  OXYGEN                   0.0
  WATER                    0.0
  CO                   5.5859-04
  CO2                  5.7303-02
  METHANE              1.9617-03
  ETHANE                   0.2072
  ETHENE               7.0584-02
COMPONENTS: LB/HR
  PROPANE              9.0036+04
  PROPENE              1.9238+05
  HYDROGEN             1.3364-04
  OXYGEN                   0.0
  WATER                    0.0
  CO                   1.5646-02
  CO2                      2.5219
  METHANE              3.1472-02
  ETHANE                   6.2314
```

```
  ETHENE                  1.9802
TOTAL FLOW:
  LBMOL/HR             6613.8679
  LB/HR               2.8243+05
  CUFT/HR              9619.8001
STATE VARIABLES:
  TEMP    F             109.6769
  PRES    PSIA          575.0000
  VFRAC                   0.0
  LFRAC                   1.0000
  SFRAC                   0.0
ENTHALPY:
  BTU/LBMOL           -1.2836+04
  BTU/LB               -300.6006
  BTU/HR              -8.4898+07
ENTROPY:
  BTU/LBMOL-R           -56.3604
  BTU/LB-R               -1.3198
DENSITY:
  LBMOL/CUFT              0.6875
  LB/CUFT                29.3591
AVG MW                   42.7024

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F             109.6769
PRES     PSIA          575.0000
HFLMX    BTU/HR      -8.4898+07

S306
----

STREAM ID                S306
FROM :                   H301
TO   :                   M301

SUBSTREAM: MIXED
PHASE:                   VAPOR
COMPONENTS: LBMOL/HR
  PROPANE              2041.7827
  PROPENE              4571.7475
  HYDROGEN             6.6292-05
  OXYGEN                  0.0
  WATER                   0.0
  CO                   5.5859-04
  CO2                  5.7303-02
  METHANE              1.9617-03
  ETHANE                  0.2072
  ETHENE               7.0584-02
COMPONENTS: LB/HR
  PROPANE              9.0036+04
  PROPENE              1.9238+05
  HYDROGEN             1.3364-04
  OXYGEN                  0.0
  WATER                   0.0
  CO                   1.5646-02
  CO2                     2.5219
  METHANE              3.1472-02
  ETHANE                  6.2314
  ETHENE                  1.9802
TOTAL FLOW:
  LBMOL/HR             6613.8679
```

```
  LB/HR               2.8243+05
  CUFT/HR             8.8463+04
STATE VARIABLES:
  TEMP    F            257.0000
  PRES    PSIA         575.0000
  VFRAC                  1.0000
  LFRAC                  0.0
  SFRAC                  0.0
ENTHALPY:
  BTU/LBMOL          -4621.4917
  BTU/LB              -108.2254
  BTU/HR             -3.0566+07
ENTROPY:
  BTU/LBMOL-R          -44.1809
  BTU/LB-R              -1.0346
DENSITY:
  LBMOL/CUFT          7.4764-02
  LB/CUFT                3.1926
AVG MW                  42.7024

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F            257.0000
PRES     PSIA         575.0000
HFLMX    BTU/HR     -3.0566+07

S307
----

STREAM ID               S307
FROM :                  M301
TO   :                  C302

SUBSTREAM: MIXED
PHASE:                  VAPOR
COMPONENTS: LBMOL/HR
  PROPANE              21.0380
  PROPENE            4186.5784
  HYDROGEN              0.0
  OXYGEN                0.0
  WATER                 0.0
  CO                    0.0
  CO2                   0.0
  METHANE               0.0
  ETHANE                0.0
  ETHENE                0.0
COMPONENTS: LB/HR
  PROPANE             927.7032
  PROPENE            1.7617+05
  HYDROGEN              0.0
  OXYGEN                0.0
  WATER                 0.0
  CO                    0.0
  CO2                   0.0
  METHANE               0.0
  ETHANE                0.0
  ETHENE                0.0
TOTAL FLOW:
  LBMOL/HR           4207.6164
  LB/HR              1.7710+05
  CUFT/HR            5.6279+04
STATE VARIABLES:
```

```
  TEMP    F              257.0000
  PRES    PSIA           575.0000
  VFRAC                    1.0000
  LFRAC                    0.0
  SFRAC                    0.0
ENTHALPY:
  BTU/LBMOL            1.1552+04
  BTU/LB                274.4508
  BTU/HR               4.8606+07
ENTROPY:
  BTU/LBMOL-R           -36.3527
  BTU/LB-R               -0.8637
DENSITY:
  LBMOL/CUFT           7.4764-02
  LB/CUFT                  3.1469
AVG MW                    42.0907

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP      F              257.0000
PRES      PSIA           575.0000
HFLMX     BTU/HR       4.8606+07

S308
----

STREAM ID                 S308
FROM :                    C302
TO   :                    C303

SUBSTREAM: MIXED
PHASE:                    VAPOR
COMPONENTS: LBMOL/HR
  PROPANE                 21.0380
  PROPENE               4186.5784
  HYDROGEN                 0.0
  OXYGEN                   0.0
  WATER                    0.0
  CO                       0.0
  CO2                      0.0
  METHANE                  0.0
  ETHANE                   0.0
  ETHENE                   0.0
COMPONENTS: LB/HR
  PROPANE                927.7032
  PROPENE              1.7617+05
  HYDROGEN                 0.0
  OXYGEN                   0.0
  WATER                    0.0
  CO                       0.0
  CO2                      0.0
  METHANE                  0.0
  ETHANE                   0.0
  ETHENE                   0.0
TOTAL FLOW:
  LBMOL/HR             4207.6164
  LB/HR                1.7710+05
  CUFT/HR              1.2493+06
STATE VARIABLES:
  TEMP    F               93.6757
  PRES    PSIA            20.0000
  VFRAC                    1.0000
```

```
  LFRAC                    0.0
  SFRAC                    0.0
ENTHALPY:
  BTU/LBMOL             8689.9830
  BTU/LB                 206.4584
  BTU/HR               3.6564+07
ENTROPY:
  BTU/LBMOL-R            -34.1963
  BTU/LB-R                -0.8124
DENSITY:
  LBMOL/CUFT           3.3680-03
  LB/CUFT                  0.1418
AVG MW                    42.0907

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F                93.6757
PRES     PSIA             20.0000
HFLMX    BTU/HR         3.6564+07

S309
----

STREAM ID                 S309
FROM :                    C303
TO   :                    HX301

SUBSTREAM: MIXED
PHASE:                    VAPOR
COMPONENTS: LBMOL/HR
  PROPANE                 21.0380
  PROPENE               4186.5784
  HYDROGEN                 0.0
  OXYGEN                   0.0
  WATER                    0.0
  CO                       0.0
  CO2                      0.0
  METHANE                  0.0
  ETHANE                   0.0
  ETHENE                   0.0
COMPONENTS: LB/HR
  PROPANE                927.7032
  PROPENE              1.7617+05
  HYDROGEN                 0.0
  OXYGEN                   0.0
  WATER                    0.0
  CO                       0.0
  CO2                      0.0
  METHANE                  0.0
  ETHANE                   0.0
  ETHENE                   0.0
TOTAL FLOW:
  LBMOL/HR              4207.6164
  LB/HR                 1.7710+05
  CUFT/HR               1.4412+05
STATE VARIABLES:
  TEMP   F               338.2659
  PRES   PSIA            250.0000
  VFRAC                    1.0000
  LFRAC                    0.0
  SFRAC                    0.0
ENTHALPY:
```

```
  BTU/LBMOL           1.3171+04
  BTU/LB               312.9268
  BTU/HR              5.5420+07
ENTROPY:
  BTU/LBMOL-R          -32.5596
  BTU/LB-R              -0.7736
DENSITY:
  LBMOL/CUFT          2.9195-02
  LB/CUFT               1.2289
AVG MW                 42.0907

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F            338.2659
PRES     PSIA         250.0000
HFLMX    BTU/HR      5.5420+07

S310
----

STREAM ID              S310
FROM :                 M301
TO   :                 C301

SUBSTREAM: MIXED
PHASE:                 VAPOR
COMPONENTS: LBMOL/HR
  PROPANE             2020.7447
  PROPENE              385.1691
  HYDROGEN            6.6292-05
  OXYGEN                 0.0
  WATER                  0.0
  CO                  5.5859-04
  CO2                 5.7303-02
  METHANE             1.9617-03
  ETHANE                 0.2072
  ETHENE              7.0584-02
COMPONENTS: LB/HR
  PROPANE             8.9108+04
  PROPENE             1.6208+04
  HYDROGEN            1.3364-04
  OXYGEN                 0.0
  WATER                  0.0
  CO                  1.5646-02
  CO2                    2.5219
  METHANE             3.1472-02
  ETHANE                 6.2314
  ETHENE                 1.9802
TOTAL FLOW:
  LBMOL/HR            2406.2515
  LB/HR               1.0533+05
  CUFT/HR             3.2185+04
STATE VARIABLES:
  TEMP   F             257.0000
  PRES   PSIA          575.0000
  VFRAC                  1.0000
  LFRAC                  0.0
  SFRAC                  0.0
ENTHALPY:
  BTU/LBMOL          -3.2902+04
  BTU/LB              -751.6762
  BTU/HR             -7.9172+07
```

```
ENTROPY:
  BTU/LBMOL-R          -60.2607
  BTU/LB-R              -1.3767
DENSITY:
  LBMOL/CUFT          7.4764-02
  LB/CUFT               3.2726
AVG MW                 43.7721

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F            257.0000
PRES     PSIA         575.0000
HFLMX    BTU/HR     -7.9172+07

S311
----

STREAM ID              S311
FROM :                 C301
TO   :                 MX301

SUBSTREAM: MIXED
PHASE:                 VAPOR
COMPONENTS: LBMOL/HR
  PROPANE           2020.7447
  PROPENE            385.1691
  HYDROGEN          6.6292-05
  OXYGEN               0.0
  WATER                0.0
  CO                5.5859-04
  CO2               5.7303-02
  METHANE           1.9617-03
  ETHANE               0.2072
  ETHENE            7.0584-02
COMPONENTS: LB/HR
  PROPANE           8.9108+04
  PROPENE           1.6208+04
  HYDROGEN          1.3364-04
  OXYGEN               0.0
  WATER                0.0
  CO                1.5646-02
  CO2                  2.5219
  METHANE           3.1472-02
  ETHANE               6.2314
  ETHENE               1.9802
TOTAL FLOW:
  LBMOL/HR          2406.2515
  LB/HR             1.0533+05
  CUFT/HR           7.3548+05
STATE VARIABLES:
  TEMP   F           109.9772
  PRES   PSIA         20.0000
  VFRAC                1.0000
  LFRAC                0.0
  SFRAC                0.0
ENTHALPY:
  BTU/LBMOL        -3.5827+04
  BTU/LB            -818.4816
  BTU/HR           -8.6208+07
ENTROPY:
  BTU/LBMOL-R         -58.1411
  BTU/LB-R             -1.3283
```

```
DENSITY:
  LBMOL/CUFT          3.2717-03
  LB/CUFT               0.1432
AVG MW                 43.7721

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F            109.9772
PRES     PSIA          20.0000
HFLMX    BTU/HR      -8.6208+07

S312
----

STREAM ID              S312
FROM :                 MX301
TO   :                 B1

SUBSTREAM: MIXED
PHASE:                 MIXED
COMPONENTS: LBMOL/HR
  PROPANE             4822.3026
  PROPENE              396.1219
  HYDROGEN            6.6292-05
  OXYGEN                 0.0
  WATER                 21.6101
  CO                  5.5859-04
  CO2                 5.7303-02
  METHANE             1.9617-03
  ETHANE                 0.2072
  ETHENE              7.0584-02
COMPONENTS: LB/HR
  PROPANE             2.1265+05
  PROPENE             1.6669+04
  HYDROGEN            1.3364-04
  OXYGEN                 0.0
  WATER                389.3114
  CO                  1.5646-02
  CO2                    2.5219
  METHANE             3.1472-02
  ETHANE                 6.2314
  ETHENE                 1.9802
TOTAL FLOW:
  LBMOL/HR            5240.3723
  LB/HR               2.2972+05
  CUFT/HR             1.1278+06
STATE VARIABLES:
  TEMP   F             -28.8264
  PRES   PSIA           20.0000
  VFRAC                  0.9306
  LFRAC               6.9396-02
  SFRAC                  0.0
ENTHALPY:
  BTU/LBMOL          -4.3507+04
  BTU/LB              -992.5094
  BTU/HR             -2.2800+08
ENTROPY:
  BTU/LBMOL-R          -66.7457
  BTU/LB-R              -1.5226
DENSITY:
  LBMOL/CUFT          4.6465-03
  LB/CUFT                0.2037
```

```
AVG MW                    43.8358

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP      F              -28.8264
PRES      PSIA            20.0000
HFLMX     BTU/HR       -2.2800+08

S313
----

STREAM ID                  S313
FROM :                     H303
TO   :                     C304

SUBSTREAM: MIXED
PHASE:                     VAPOR
COMPONENTS: LBMOL/HR
  PROPANE                4340.0723
  PROPENE                 356.5097
  HYDROGEN               5.9663-05
  OXYGEN                    0.0
  WATER                    19.4491
  CO                     5.0273-04
  CO2                    5.1573-02
  METHANE                1.7656-03
  ETHANE                    0.1865
  ETHENE                 6.3526-02
COMPONENTS: LB/HR
  PROPANE                1.9138+05
  PROPENE                1.5002+04
  HYDROGEN               1.2027-04
  OXYGEN                    0.0
  WATER                   350.3802
  CO                     1.4082-02
  CO2                       2.2697
  METHANE                2.8324-02
  ETHANE                    5.6082
  ETHENE                    1.7821
TOTAL FLOW:
  LBMOL/HR               4716.3350
  LB/HR                  2.0674+05
  CUFT/HR                1.3445+06
STATE VARIABLES:
  TEMP    F                71.6000
  PRES    PSIA             20.0000
  VFRAC                     1.0000
  LFRAC                     0.0
  SFRAC                     0.0
ENTHALPY:
  BTU/LBMOL             -4.1282+04
  BTU/LB                 -941.7367
  BTU/HR                -1.9470+08
ENTROPY:
  BTU/LBMOL-R            -62.0035
  BTU/LB-R                -1.4144
DENSITY:
  LBMOL/CUFT             3.5080-03
  LB/CUFT                   0.1538
AVG MW                    43.8358

MIXED    SUBSTREAM PROPERTIES:
```

```
***  ALL PHASES   ***
TEMP     F              71.6000
PRES     PSIA           20.0000
HFLMX    BTU/HR      -1.9470+08

S314
----

STREAM ID               S314
FROM :                  C304
TO   :                  MX102

SUBSTREAM: MIXED
PHASE:                  VAPOR
COMPONENTS: LBMOL/HR
  PROPANE             4340.0723
  PROPENE              356.5097
  HYDROGEN            5.9663-05
  OXYGEN                0.0
  WATER                19.4491
  CO                  5.0273-04
  CO2                 5.1573-02
  METHANE             1.7656-03
  ETHANE                0.1865
  ETHENE              6.3526-02
COMPONENTS: LB/HR
  PROPANE             1.9138+05
  PROPENE             1.5002+04
  HYDROGEN            1.2027-04
  OXYGEN                0.0
  WATER                350.3802
  CO                  1.4082-02
  CO2                   2.2697
  METHANE             2.8324-02
  ETHANE                5.6082
  ETHENE                1.7821
TOTAL FLOW:
  LBMOL/HR            4716.3350
  LB/HR               2.0674+05
  CUFT/HR             4.4694+05
STATE VARIABLES:
  TEMP    F            180.7066
  PRES    PSIA          72.5189
  VFRAC                  1.0000
  LFRAC                  0.0
  SFRAC                  0.0
ENTHALPY:
  BTU/LBMOL          -3.9253+04
  BTU/LB              -895.4494
  BTU/HR             -1.8513+08
ENTROPY:
  BTU/LBMOL-R          -61.0957
  BTU/LB-R              -1.3937
DENSITY:
  LBMOL/CUFT          1.0553-02
  LB/CUFT               0.4626
AVG MW                 43.8358

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP     F            180.7066
```

```
PRES      PSIA           72.5189
HFLMX     BTU/HR      -1.8513+08

S315
----

STREAM ID                S315
FROM :                   HX301
TO   :                   H302

SUBSTREAM: MIXED
PHASE:                   VAPOR
COMPONENTS: LBMOL/HR
  PROPANE                21.0380
  PROPENE              4186.5784
  HYDROGEN                0.0
  OXYGEN                  0.0
  WATER                   0.0
  CO                      0.0
  CO2                     0.0
  METHANE                 0.0
  ETHANE                  0.0
  ETHENE                  0.0
COMPONENTS: LB/HR
  PROPANE               927.7032
  PROPENE              1.7617+05
  HYDROGEN                0.0
  OXYGEN                  0.0
  WATER                   0.0
  CO                      0.0
  CO2                     0.0
  METHANE                 0.0
  ETHANE                  0.0
  ETHENE                  0.0
TOTAL FLOW:
  LBMOL/HR             4207.6164
  LB/HR                1.7710+05
  CUFT/HR              1.4203+05
STATE VARIABLES:
  TEMP    F             326.7204
  PRES    PSIA          250.0000
  VFRAC                   1.0000
  LFRAC                   0.0
  SFRAC                   0.0
ENTHALPY:
  BTU/LBMOL            1.2934+04
  BTU/LB                307.2803
  BTU/HR               5.4420+07
ENTROPY:
  BTU/LBMOL-R           -32.8596
  BTU/LB-R               -0.7807
DENSITY:
  LBMOL/CUFT           2.9624-02
  LB/CUFT                 1.2469
AVG MW                   42.0907

MIXED    SUBSTREAM PROPERTIES:

***  ALL PHASES   ***
TEMP      F             326.7204
PRES      PSIA          250.0000
HFLMX     BTU/HR       5.4420+07
```

S316

STREAM ID		S316
FROM :		H302
TO :		----
SUBSTREAM: MIXED		
PHASE:		LIQUID
COMPONENTS: LBMOL/HR		
PROPANE		21.0380
PROPENE		4186.5784
HYDROGEN		0.0
OXYGEN		0.0
WATER		0.0
CO		0.0
CO2		0.0
METHANE		0.0
ETHANE		0.0
ETHENE		0.0
COMPONENTS: LB/HR		
PROPANE		927.7032
PROPENE		1.7617+05
HYDROGEN		0.0
OXYGEN		0.0
WATER		0.0
CO		0.0
CO2		0.0
METHANE		0.0
ETHANE		0.0
ETHENE		0.0
TOTAL FLOW:		
LBMOL/HR		4207.6164
LB/HR		1.7710+05
CUFT/HR		5849.6963
STATE VARIABLES:		
TEMP	F	100.0000
PRES	PSIA	250.0000
VFRAC		0.0
LFRAC		1.0000
SFRAC		0.0
ENTHALPY:		
BTU/LBMOL		3161.5962
BTU/LB		75.1139
BTU/HR		1.3303+07
ENTROPY:		
BTU/LBMOL-R		-48.9159
BTU/LB-R		-1.1622
DENSITY:		
LBMOL/CUFT		0.7193
LB/CUFT		30.2753
AVG MW		42.0907

MIXED SUBSTREAM PROPERTIES:

*** ALL PHASES ***		
TEMP	F	100.0000
PRES	PSIA	250.0000
HFLMX	BTU/HR	1.3303+07

SIGMA-ALDRICH

sigma-aldrich.com

SAFETY DATA SHEET

Version 5.3
Revision Date 06/30/2014
Print Date 04/01/2016

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product identifiers

Product name : 2-Methylimidazole

Product Number : M50850
Brand : Aldrich

CAS-No. : 693-98-1

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Manufacture of substances

1.3 Details of the supplier of the safety data sheet

Company : Sigma-Aldrich
3050 Spruce Street
SAINT LOUIS MO 63103
USA

Telephone : +1 800-325-5832
Fax : +1 800-325-5052

1.4 Emergency telephone number

Emergency Phone # : (314) 776-6555

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)
Acute toxicity, Oral (Category 4), H302
Skin corrosion (Category 1B), H314
Serious eye damage (Category 1), H318

For the full text of the H-Statements mentioned in this Section, see Section 16.

2.2 GHS Label elements, including precautionary statements

Pictogram

Signal word Danger

Hazard statement(s)
H302 Harmful if swallowed.
H314 Causes severe skin burns and eye damage.

Precautionary statement(s)
P260 Do not breathe dust or mist.
P264 Wash skin thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.
P280 Wear protective gloves/ protective clothing/ eye protection/ face protection.
P301 + P312 IF SWALLOWED: Call a POISON CENTER or doctor/ physician if you feel unwell.
P301 + P330 + P331 IF SWALLOWED: rinse mouth. Do NOT induce vomiting.
P303 + P361 + P353 IF ON SKIN (or hair): Remove/ Take off immediately all contaminated clothing. Rinse skin with water/ shower.
P304 + P340 IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.
P305 + P351 + P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P310 Immediately call a POISON CENTER or doctor/ physician.
P321 Specific treatment (see supplemental first aid instructions on this label).
P363 Wash contaminated clothing before reuse.
P405 Store locked up.
P501 Dispose of contents/ container to an approved waste disposal plant.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

3. COMPOSITION/INFORMATION ON INGREDIENTS

3.1 Substances

Synonyms : 2-Methylglyoxaline

Formula : $C_4H_6N_2$
Molecular Weight : 82.10 g/mol
CAS-No. : 693-98-1
EC-No. : 211-765-7

Hazardous components

Component	Classification	Concentration
2-Methylimidazole		
	Acute Tox. 4; Skin Corr. 1B; Eye Dam. 1; H302, H314	90 - 100 %

For the full text of the H-Statements mentioned in this Section, see Section 16.

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance.Move out of dangerous area.

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact
Take off contaminated clothing and shoes immediately. Wash off with soap and plenty of water. Consult a physician.

In case of eye contact
Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.Continue rinsing eyes during transport to hospital.

If swallowed
Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

4.3 Indication of any immediate medical attention and special treatment needed
no data available

5. FIREFIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

5.2 Special hazards arising from the substance or mixture
Carbon oxides, nitrogen oxides (NOx)

5.3 Advice for firefighters
Wear self contained breathing apparatus for fire fighting if necessary.

5.4 Further information
no data available

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures
Use personal protective equipment. Avoid dust formation. Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Evacuate personnel to safe areas. Avoid breathing dust.
For personal protection see section 8.

6.2 Environmental precautions
Do not let product enter drains.

6.3 Methods and materials for containment and cleaning up
Pick up and arrange disposal without creating dust. Sweep up and shovel. Keep in suitable, closed containers for disposal.

6.4 Reference to other sections
For disposal see section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling
Avoid contact with skin and eyes. Avoid formation of dust and aerosols.
Provide appropriate exhaust ventilation at places where dust is formed.
For precautions see section 2.2.

7.2 Conditions for safe storage, including any incompatibilities
Keep container tightly closed in a dry and well-ventilated place.

Keep in a dry place.

7.3 Specific end use(s)
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
Contains no substances with occupational exposure limit values.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

Personal protective equipment

Eye/face protection
Face shield and safety glasses Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Full contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min

Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

Splash contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

Body Protection
Complete suit protecting against chemicals, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Respiratory protection
Where risk assessment shows air-purifying respirators are appropriate use a full-face particle respirator type N100 (US) or type P3 (EN 143) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Control of environmental exposure
Do not let product enter drains.

9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: powder
b)	Odour	no data available
c)	Odour Threshold	no data available
d)	pH	no data available
e)	Melting point/freezing point	Melting point/range: 142 - 143 °C (288 - 289 °F) - lit.
f)	Initial boiling point and boiling range	267 - 268 °C (513 - 514 °F) - lit.
g)	Flash point	no data available
h)	Evapouration rate	no data available
i)	Flammability (solid, gas)	no data available
j)	Upper/lower flammability or explosive limits	no data available
k)	Vapour pressure	no data available
l)	Vapour density	no data available
m)	Relative density	no data available
n)	Water solubility	no data available
o)	Partition coefficient: n-octanol/water	no data available
p)	Auto-ignition temperature	no data available
q)	Decomposition temperature	no data available

r) Viscosity no data available

s) Explosive properties no data available

t) Oxidizing properties no data available

9.2 Other safety information
no data available

10. STABILITY AND REACTIVITY

10.1 Reactivity
no data available

10.2 Chemical stability
Stable under recommended storage conditions.

10.3 Possibility of hazardous reactions
no data available

10.4 Conditions to avoid
no data available

10.5 Incompatible materials
Strong oxidizing agents, acids, Acid chlorides, Acid anhydrides

10.6 Hazardous decomposition products
Other decomposition products - no data available
In the event of fire: see section 5

11. TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity
LD50 Oral - mouse - 1,400 mg/kg
Remarks: Behavioral:Convulsions or effect on seizure threshold.

Inhalation: no data available

Dermal: no data available

no data available

Skin corrosion/irritation
no data available

Serious eye damage/eye irritation
no data available

Respiratory or skin sensitisation
no data available

Germ cell mutagenicity
no data available

Carcinogenicity

IARC: 2B - Group 2B: Possibly carcinogenic to humans (2-Methylimidazole)

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity
no data available

no data available

Specific target organ toxicity - single exposure
no data available

Specific target organ toxicity - repeated exposure
no data available

Aspiration hazard
no data available

Additional Information
RTECS: NI7175000

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity

Toxicity to fish LC50 - Pimephales promelas (fathead minnow) - 286 mg/l - 96 h

12.2 Persistence and degradability
no data available

12.3 Bioaccumulative potential
no data available

12.4 Mobility in soil
no data available

12.5 Results of PBT and vPvB assessment
PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

12.6 Other adverse effects

no data available

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Offer surplus and non-recyclable solutions to a licensed disposal company. Contact a licensed professional waste disposal service to dispose of this material. Dissolve or mix the material with a combustible solvent and burn in a chemical incinerator equipped with an afterburner and scrubber.

Contaminated packaging
Dispose of as unused product.

14. TRANSPORT INFORMATION

DOT (US)
UN number: 3259 Class: 8 Packing group: II
Proper shipping name: Polyamines, solid, corrosive n.o.s. (2-Methylimidazole)
Reportable Quantity (RQ):
Marine pollutant: No
Poison Inhalation Hazard: No

IMDG
UN number: 3259 Class: 8 Packing group: II EMS-No: F-A, S-B
Proper shipping name: POLYAMINES, SOLID, CORROSIVE, N.O.S. (2-Methylimidazole)
Marine pollutant: No

IATA
UN number: 3259 Class: 8 Packing group: II
Proper shipping name: Polyamines, solid, corrosive, n.o.s. (2-Methylimidazole)

CLEARTECH

MATERIAL SAFETY DATA SHEET

Activated Carbon

Section 01 - Chemical And Product And Company Information

Product Identifier ..... Activated carbon (All Grades)

Product Use ..... Water purification, gold recovery, and air scrubbing

Supplier Name..... ClearTech Industries Inc.
1500 Quebec Avenue
Saskatoon, SK. Canada
S7K 1V7

Prepared By..... ClearTech Industries Inc. Technical Department
Phone: 1 (800) 387-7503

Preparation Date..... February 16, 2009

24-Hour Emergency Phone..... 1 (800) 387-7503

Section 02 - Composition / Information on Ingredients

Hazardous Ingredients.....	Activate Carbon	100%
CAS Number.....	Activated Carbon	7440-44-0
Synonym (s).....	Activated granular carbon, activated powdered carbon, pelleted activated carbon, activated charcoal, animal bone black,	

Section 03 - Hazard Identification

Inhalation..... Non-toxic though inhalation

Skin Contact / Absorption..... Not Available

Eye Contact..... Mechanical dust irritation

Ingestion..... Non-toxic though ingestion

Exposure Limits..... OSHA/PEL= 5mg/m^3 as resp.
ACGIH/TLV= 10mg/m^3 as total

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
Acute Health Hazard, Chronic Health Hazard

Massachusetts Right To Know Components
No components are subject to the Massachusetts Right to Know Act.

Pennsylvania Right To Know Components

	CAS-No.	Revision Date
2-Methylimidazole	693-98-1	

New Jersey Right To Know Components

	CAS-No.	Revision Date
2-Methylimidazole	693-98-1	

California Prop. 65 Components

	CAS-No.	Revision Date
WARNING! This product contains a chemical known to the State of California to cause cancer. 2-Methylimidazole	693-98-1	2012-07-20

16. OTHER INFORMATION

Full text of H-Statements referred to under sections 2 and 3.

Acute Tox.	Acute toxicity
Eye Dam.	Serious eye damage
H302	Harmful if swallowed.
H314	Causes severe skin burns and eye damage.
H318	Causes serious eye damage.
Skin Corr.	Skin corrosion

HMIS Rating

Health hazard:	3
Chronic Health Hazard:	*
Flammability:	0
Physical Hazard	0

NFPA Rating

Health hazard:	3
Fire Hazard:	0
Reactivity Hazard:	0

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

Section 06 - Accidental Release Measures

Leak / Spill..... Wear appropriate personal protective equipment. Ventilate area. Stop or reduce leak if safe to do so. Prevent material from entering sewers. Vacuum or shovel spilled material and place in closed container for proper disposal.

Deactivating Materials..... Not Available

Section 07 - Handling and Storage

Handling Procedures..... Use proper equipment for lifting and transporting all containers. Use sensible industrial hygiene and housekeeping practices. Wash thoroughly after handling. Avoid all situations that could lead to harmful exposure.

Storage Requirements..... Store in a clean, well ventilated area away from oxidizers, acids, ignition sources, heat and combustible materials.

Section 08 - Personal Protection and Exposure Controls

Protective Equipment

Eyes..... Chemical goggles, full-face shield, or a full-face respirator is to be worn at all times when product is handled. Contact lenses should not be worn; they may contribute to severe eye injury.

Respiratory..... Respiratory protection is not normally required. If use creates dust formations, then a NIOSH-approved respirator with a dust cartridge is recommended. Wet activated carbon removes oxygen from air causing a severe hazard to workers inside confined spaces. Before entering such an area, sampling and work procedures for low oxygen levels should be taken (such as wearing a self-contained breathing apparatus).

Gloves..... Impervious gloves of chemically resistant material (rubber or PVC) should be worn. Wash contaminated clothing and dry thoroughly before reuse.

Clothing..... Body suits, aprons, and/or coveralls of chemical resistant material should be worn at all times. Wash contaminated clothing and dry thoroughly before reuse.

Footwear..... No special footwear is required other than what is mandated at place of work.

Other..... Not Available

Section 04 - First Aid Measures

Inhalation..... Remove victim to fresh air. Give artificial respiration only if breathing has stopped. If breathing is difficult, give oxygen. Seek medical attention.

Skin Contact / Absorption..... Remove contaminated clothing. Wash affected area with soap and water. Seek medical attention if irritation occurs or persists.

Eye Contact..... Flush immediately with water for at least 20 minutes. Forcibly hold eyelids apart to ensure complete irrigation of eye tissue. Seek medical attention.

Ingestion..... No known health effects. Seek medical attention if any problems are experienced.

Additional Information..... Not Available

Section 05 - Fire Fighting

Conditions of Flammability..... Non-combustible under normal circumstances. Once ignited, the fire generally burns slowly (smolder) with a dull glow and may be difficult to detect.

Means of Extinction..... Use water spray, alcohol foam, dry chemical or carbon dioxide.

Flash Point..... Not Applicable

Auto-ignition Temperature..... > 220°C

Upper Flammable Limit ..... Not Applicable

Lower Flammable Limit..... Not Applicable

Hazardous Combustible Products.... Carbon monoxide, formaldehyde, and carbon dioxide. Contact with strong oxidizers (ozone, liquid oxygen) may cause rapid combustion.

Special Fire Fighting Procedures..... Wear NIOSH-approved self-contained breathing apparatus and protective clothing.

Explosion Hazards..... Airborne dust may create an explosion hazard.

CLEARTECH

Engineering Controls

Ventilation Requirements..... Mechanical ventilation (dilution or local exhaust), process or personnel enclosure and control of process conditions should be provided. Supply sufficient replacement air to make up for air removed by exhaust systems.

Other..... Emergency shower and eyewash should be in close proximity.

Section 09 - Physical and Chemical Properties

Physical State..... Solid

Odor and Appearance..... Black odourless particulate solid, pellet, or powder

Odor Threshold..... Not Applicable

Specific Gravity (Water=1)..... 0.25 – 0.60

Vapor Pressure (mm Hg, 20°C)..... Not Applicable

Vapor Density (Air=1)..... Not Applicable

Evaporation Rate..... Not Applicable

Boiling Point..... Maximum 4000°C

Freeze/Melting Point..... > 3500°C

pH..... Not Applicable

Water/Oil Distribution Coefficient..... Not Applicable

Bulk Density..... > 400kg/m^3

% Volatiles by Volume..... 0%

Solubility in Water..... Insoluble

Molecular Formula..... C

Molecular Weight..... 12.011

CLEARTECH

Section 10 - Stability and Reactivity

Stability..... Stable under normal conditions.

Incompatibility..... Strong oxidizers such as ozone, liquid oxygen, chlorine, potassium permanganate.

Hazardous Products of Decomposition.. Carbon monoxide may be generated in the event of a fire (especially with incomplete combustion in an enclosed space).

Polymerization..... Will not occur

Section 11 - Toxicological Information

Irritancy..... Not Available

Sensitization..... Not Available

Chronic/Acute Effects..... Not Available

Synergistic Materials..... Not Available

Animal Toxicity Data..... LD_{50}(rat,oral): >10g/kg
LC_{50}(rat, inhalation): >64.4mg/L

Carcinogenicity..... Not considered to be carcinogenic as per IARC, NTP, and OSHA.

Reproductive Toxicity..... Not Available

Teratogenicity..... Not Available

Mutagenicity..... Not Available

Section 12 - Ecological Information

Fish Toxicity..... Not Available

Biodegradability..... Not Available

Environmental Effects..... Not Available

Section 13 - Disposal Considerations

Waste Disposal..... Dispose in accordance with all federal, provincial, and/or local regulations including the Canadian Environmental Protection Act.

Section 14 - Transportation Information

TDG Classification

Class..... Not regulated

Group..... Not regulated

PIN Number..... Not regulated

Other..... Secure containers (full and/or empty) with suitable hold down devises during shipment.

Section 15 - Regulatory Information

WHMIS Classification.....Not a controlled product

Revision Date.....December 19, 2013

NOTE: THE PRODUCT LISTED ON THIS MSDS HAS BEEN CLASSIFIED IN ACCORDANCE WITH THE HAZARD CRITERIA OF THE CANADIAN CONTROLLED PRODUCTS REGULATIONS. THIS MSDS CONTAINS ALL INFORMATION REQUIRED BY THOSE REGULATIONS.

Section 16 - Other Information

Note: The responsibility to provide a safe workplace remains with the user. The user should consider the health hazards and safety information contained herein as a guide and should take those precautions required in an individual operation to instruct employees and develop work practice procedures for a safe work environment. The information contained herein is, to the best of our knowledge and belief, accurate. However, since the conditions of handling and use are beyond our control, we make no guarantee of results, and assume no liability for damages incurred by the use of this material. It is the responsibility of the user to comply with all applicable laws and regulations.

Attention: Receiver of the chemical goods / MSDS coordinator

As part of our commitment to the Canadian Association of Chemical Distributors (CACD) Responsible Distribution© initiative, ClearTech Industries Inc. and its associated companies require, as a condition of sale, that you forward the attached Material Safety Data Sheet(s) to all affected employees, customers, and end-users. ClearTech will send any available supplementary handling, health, and safety information to you at your request.

If you have any questions or concerns please call our customer service or technical service department.

ClearTech Industries Inc. - Locations

Corporate Head Office: 1500 Quebec Avenue, Saskatoon, SK, S7K 1V7
Phone: 306-664-2522
Fax: 306-665-6216

www.ClearTech.ca

Location	Address	Postal Code	Phone Number	Fax Number
Richmond, B.C.	12431 Horseshoe Way	V7A 4X6	1 (800) 387-7503	1 (888) 281-8109
Port Coquitlam, B.C.	2023 Kingsway Ave	V3C 1S9	1 (800) 387-7503	1 (888) 281-8109
Calgary, AB.	5516E - 40th St. S.E.	T2C 2A1	1 (800) 387-7503	1 (888) 281-8109
Edmonton, AB.	11750 - 180th Street	T5S 1N7	1 (800) 387-7503	1 (888) 281-8109
Saskatoon, SK.	2302 Hanselman Avenue	S7L 5Z3	1 (800) 387-7503	1 (888) 281-8109
Regina, SK.	555 Henderson Drive	S42 5X2	1 (800) 387-7503	1 (888) 281-8109
Winnipeg, MB.	340 Saulteaux Crescent	R3J 3T2	1 (800) 387-7503	1 (888) 281-8109
Mississauga, ON.	7480 Bath Road	L4T 1L2	1 (800) 387-7503	1 (888) 281-8109

24 Hour Emergency Number - All Locations – 1 (800) 387-7503

SYMPTOMS: Headache, sweating, rapid breathing, increased heartbeat, shortness of breath, dizziness, mental depression, visual disturbances, and shaking.

CHRONIC EFFECTS: None established.

MEDICAL CONDITIONS AGGRAVATED BY OVEREXPOSURE: None

CARCINOGENICITY: Carbon dioxide is not listed by NTP, OSHA or IARC.

SECTION 4. FIRST AID

INHALATION: Persons suffering from overexposure should be moved to fresh air. If victim is not breathing, administer artificial respiration. If breathing is difficult, administer oxygen. Obtain prompt medical attention.

EYE CONTACT: Contact with liquid or cold vapor can cause freezing of tissue. Gently flush eyes with lukewarm water. Obtain medical attention immediately.

SKIN CONTACT: Contact with liquid or cold vapor can cause frostbite. Immediately warm affected area with lukewarm water not to exceed 107 °F.

NOTES TO PHYSICIAN: There is no specific antidote. Treatment for overexposure should be directed at the control of symptoms and the clinical condition.

SECTION 5. FIRE AND EXPLOSION

FLASH POINT: Not Applicable

AUTOIGNITION: Nonflammable

FLAMMABLE LIMITS: Nonflammable

EXTINGUISHING MEDIA: Carbon dioxide is nonflammable and does not support combustion. Carbon dioxide is an extinguishing agent for class B and C fires. Use extinguishing media appropriate for the surrounding fire.

HAZARDOUS COMBUSTION PRODUCTS: None known.

FIRE FIGHTING PROCEDURES: Evacuate personnel from danger area. Carbon dioxide is nonflammable. If possible, without risk, remove cylinders from fire area or cool with water. Self contained breathing apparatus (SCBA) may be required for rescue workers.

UNUSUAL HAZARDS: Upon exposure to intense heat or flame, cylinder will vent rapidly and or rupture violently. Most cylinders are designed to vent contents when exposed to elevated temperatures. Pressure in a container can build up due to heat and it may rupture if pressure relief devices should fail to function.

SECTION 6. ACCIDENTAL RELEASE MEASURES

Evacuate all personnel from affected area. Increase ventilation to release area and monitor oxygen level. Use appropriate protective equipment (SCBA). If leak is from cylinder or cylinder valve call the Air Products emergency telephone number. If leak is in user's system close cylinder valve and vent pressure before attempting repairs.

SECTION 7. HANDLING AND STORAGE

STORAGE: Cylinders should be stored upright in a well-ventilated, secure area, protected from the weather. Storage area temperatures should not exceed 125 °F (52 °C). Storage should be away from heavily traveled areas and emergency exits. Avoid areas where salt or other corrosive materials are present. Valve protection caps and valve outlet seals should remain on cylinders not connected for use. Separate full from empty cylinders. Avoid excessive inventory and storage time. Use a first-in first-out system. Keep good inventory records.

HANDLING: Use a suitable hand truck for cylinder movement. Never attempt to lift a cylinder by its valve protection valve cap. Never apply flame or localized heat directly to any part of the cylinder. Do not

AIR PRODUCTS

MATERIAL SAFETY DATA SHEET

SECTION 1. PRODUCT IDENTIFICATION

PRODUCT NAME: **Carbon Dioxide**

CHEMICAL NAME: Carbon Dioxide **FORMULA:** CO_2

SYNONYMS: Carbonic Anhydride, Carbonic Acid Gas, Carbon Anhydride

MANUFACTURER: **Air Products and Chemicals, Inc.**
7201 Hamilton Boulevard
Allentown, PA 18195-1501

PRODUCT INFORMATION: 1 - 800 - 752 - 1597

MSDS NUMBER: 1005 **REVISION:** 5

REVISION DATE: March 1993 **REVIEW DATE:** March 1994

SECTION 2. COMPOSITION / INFORMATION ON INGREDIENTS

CONCENTRATION: Carbon dioxide is sold as pure product > 99%.

CAS NUMBER: 124-38-9

EXPOSURE LIMITS:
OSHA: PEL-TWA = 5000 ppm **ACGIH:** TLV-TWA = 5000 ppm **NIOSH:** None established

SECTION 3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

Carbon dioxide is a nonflammable liquefied compressed gas packaged in cylinders under its own vapor pressure of 838 psig at 70 °F (21.1 °C). High concentrations can cause rapid suffocation and can also increase respiration and heart rate. Contact with liquid may cause frostbite. Avoid breathing gas. Self contained breathing apparatus (SCBA) may be required by rescue workers.

EMERGENCY TELEPHONE NUMBERS

800 - 523 - 9374 **Continental U.S., Canada, or Puerto Rico**
610 - 481 - 7711 **other locations**

POTENTIAL HEALTH EFFECTS:

INHALATION: Carbon dioxide is an asphyxiant. Concentrations of 10% or more can produce unconsciousness or death.

EYE CONTACT: Contact with liquid or cold vapor can cause freezing of tissue.

SKIN CONTACT: Contact with liquid or cold vapor can cause frostbite.

EXPOSURE INFORMATION:

ROUTE OF ENTRY: Inhalation

TARGET ORGANS: Central nervous system

EFFECT: Asphyxiation (suffocation). Overexposure may cause damage to retinal ganglion cells and central nervous system.

allow any part of the cylinder to exceed 125 °F (52 °C). High temperature may cause damage to cylinder and/or premature failure of pressure relief device which will result in venting of cylinder contents. If user experiences any difficulty operating cylinder valve discontinue use and contact supplier. Never insert an object (e.g., wrench, screwdriver, pry bar, etc.) into valve cap openings. Doing so may damage valve causing a leak to occur. Use an adjustable strap wrench to remove over-tight or rusted caps.

Only the proper CGA connections should be used, never use adapters. Use piping and equipment adequately designed to withstand pressures to be encountered. If liquid product is being used ensure steps have been taken to prevent entrapment of liquid in closed systems. The use of pressure relief devices may be necessary. Use a check valve or other protective apparatus in any line or piping from the cylinder to prevent reverse flow.

Carbon dioxide is compatible with all common materials of construction. Pressure requirements should be considered when selecting materials and designing systems.

Use a "FULL", "IN USE", and "EMPTY" tag system on cylinders. This will reduce the chances of inadvertently connecting or operating the wrong cylinder.

SPECIAL REQUIREMENTS: Always store and handle compressed gases in accordance with Compressed Gas Association, Inc. (ph. 703-979-0900) pamphlet CGA P-1, *Safe Handling of Compressed Gases in Containers*. Local regulations may require specific equipment for storage or use.

CAUTION: Compressed gas cylinders shall not be refilled except by qualified producers of compressed gases. Shipment of a compressed gas cylinder which has not been filled by the owner or with the owner's written consent is a violation of federal law.

SECTION 8. PERSONAL PROTECTION / EXPOSURE CONTROL

ENGINEERING CONTROLS: Provide ventilation and/or local exhaust to prevent accumulation of carbon dioxide concentrations above 5000 ppm.

RESPIRATORY PROTECTION:

Emergency Use: Self contained breathing apparatus (SCBA) or positive pressure airline with mask and escape pack are to be used in oxygen deficient atmosphere. Air purifying respirators will not provide protection.

EYE PROTECTION: Safety glasses are recommended when handling, connecting, or disconnecting cylinders, and when pressurizing systems

OTHER PROTECTIVE EQUIPMENT: Safety shoes and leather work gloves when handling cylinders.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE, ODOR AND STATE: Colorless and odorless. A slightly acid gas. It is felt by some to have a slight pungent odor and biting taste.

MOLECULAR WEIGHT: 44.01

GAS DENSITY (at 70 °F (21.1 °C) and 1 atm): 0.1144 lb/ft^3 (1.832 kg/m^3)

VAPOR PRESSURE (at 70 °F (21.1 °C)): 838 psig

SPECIFIC GRAVITY (Air =1): 1.522

SPECIFIC VOLUME (at 70 °F (21.1 °C) and 1 atm): 8.74 ft^3/lb (0.5457 m^3/kg)

BOILING POINT: -109.3 °F (-78.5 °C)

TRIPLE POINT (At 60.4 psig): -69.9 °F (-56.6 °C)

SOLUBILITY IN WATER (Vol./Vol. at 68 °F (20 °C)): 0.90

SECTION 10. STABILITY AND REACTIVITY

STABILITY: Stable

CONDITIONS TO AVOID: None

INCOMPATIBILITY (Materials to Avoid): None

REACTIVITY:

HAZARDOUS DECOMPOSITION PRODUCTS: None

HAZARDOUS POLYMERIZATION: Will not occur

SECTION 11. TOXICOLOGICAL INFORMATION

Carbon dioxide is an asphyxiant. It initially stimulates respiration and then causes respiratory depression. High concentrations result in narcosis. Symptoms in humans are as follows:

CONCENTRATION	EFFECT
1%	Slight increase in breathing rate
2%	Breathing rate increases to 50% above normal. Prolonged exposure can cause headache and tiredness.
3%	Breathing increases to twice the normal rate and becomes labored. Weak narcotic effect. Impaired hearing, headache, increase in blood pressure and pulse rate.
4-5%	Breathing increases to approximately four times the normal rate, symptoms of intoxication become evident and slight choking may be felt.
5-10%	Characteristic sharp odor noticeable. Very labored breathing, headache, visual impairment and ringing in the ears. Judgment may be impaired, followed within minutes by loss of consciousness.
50-100%	Unconsciousness occurs more rapidly above 10% level. Prolonged exposure to high concentrations may eventually result in death from asphyxiation.

SECTION 12. ECOLOGICAL INFORMATION

No adverse ecological effects are expected. No adverse ecological effects are expected. Carbon dioxide does not contain any Class I or Class II ozone depleting chemicals. Carbon dioxide is not listed as a marine pollutant by DOT (49 CFR 171).

SECTION 13. DISPOSAL

UNUSED PRODUCT / EMPTY CYLINDER: Return cylinder and unused product to supplier. Do not attempt to dispose of unused product. Ensure cylinder valve is properly closed, valve outlet cap has been reinstalled, and valve protection cap is secured before shipping cylinder.

WASTE DISPOSAL METHODS: For emergency disposal, secure the cylinder and slowly discharge gas to the atmosphere in a well ventilated area or outdoors. Small amounts may be disposed of by reacting with a mild base.

SECTION 14. TRANSPORT INFORMATION

DOT SHIPPING NAME: Carbon dioxide

HAZARD CLASS: 2.2 (Nonflammable Gas)

IDENTIFICATION NUMBER: UN1013

SAFETY DATA SHEET

Carbon Monoxide

Section 1. Identification

GHS product identifier	:	Carbon Monoxide
Chemical name	:	carbon monoxide
Other means of identification	:	Carbon oxide (CO); CO; Exhaust gas; Flue gas; Carbonic oxide; Carbon oxide; Carbone (oxyde de); Carbonio (ossido di); Kohlenmonoxid; Kohlenoxyd; Koolmonoxyde; NA 9202; Oxyde de carbone; UN 1016; Wegla tlenek; Carbon monooxide
Product use	:	Synthetic/Analytical chemistry.
Synonym	:	Carbon oxide (CO); CO; Exhaust gas; Flue gas; Carbonic oxide; Carbon oxide; Carbone (oxyde de); Carbonio (ossido di); Kohlenmonoxid; Kohlenoxyd; Koolmonoxyde; NA 9202; Oxyde de carbone; UN 1016; Wegla tlenek; Carbon monooxide
SDS #	:	001014
Supplier's details	:	Airgas USA, LLC and its affiliates 259 North Radnor-Chester Road Suite 100 Radnor, PA 19087-5283 1-610-687-5253
Emergency telephone number (with hours of operation)	:	1-866-734-3438

Section 2. Hazards identification

OSHA/HCS status	:	This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200).
Classification of the substance or mixture	:	FLAMMABLE GASES - Category 1 GASES UNDER PRESSURE - Compressed gas ACUTE TOXICITY (inhalation) - Category 3 TOXIC TO REPRODUCTION (Fertility) - Category 1 TOXIC TO REPRODUCTION (Unborn child) - Category 1 SPECIFIC TARGET ORGAN TOXICITY (REPEATED EXPOSURE) - Category 1

GHS label elements

Hazard pictograms :

Signal word : Danger

Hazard statements :
Extremely flammable gas.
May form explosive mixtures with air.
Contains gas under pressure; may explode if heated.
Asphyxiating even with adequate oxygen.
Toxic if inhaled.
May damage fertility or the unborn child.
Causes damage to organs through prolonged or repeated exposure.

Precautionary statements

PRODUCT RQ: None
SHIPPING LABEL(s): Nonflammable gas
PLACARD (when required): Nonflammable gas
SPECIAL SHIPPING INFORMATION: Cylinders should be transported in a secure upright position in a well ventilated truck. Never transport in passenger compartment of a vehicle.

SECTION 15. REGULATORY INFORMATION

U.S. FEDERAL REGULATIONS:

ENVIRONMENTAL PROTECTION AGENCY (EPA):

CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act of 1980 requires notification to the National Response Center of a release of quantities of hazardous substances equal to or greater than the reportable quantities (RQ's) in 40 CFR 302.4.

CERCLA Reportable Quantity: None.

SARA TITLE III: Superfund Amendment and Reauthorization Act of 1986

SECTION 302/304: Requires emergency planning on threshold planning quantities (TPQ) and release reporting based on reportable quantities (RQ) of EPA's extremely hazardous substances (40 CFR 355).

Extremely Hazardous Substances: None

Threshold Planning Quantity (TPQ): None

SECTIONS 311/312: Require submission of material safety data sheets (MSDSs) and chemical inventory reporting with identification of EPA defined hazard classes. The hazard classes for this product are:

IMMEDIATE HEALTH: Yes
DELAYED HEALTH: No
PRESSURE: Yes
REACTIVITY: No
FLAMMABLE: No

SECTION 313: Requires submission of annual reports of release of toxic chemicals that appear in 40 CFR 372.

Carbon dioxide does not require reporting under Section 313

40 CFR Part 68 - Risk Management for Chemical Accident Release Prevention: Requires the development and implementation of risk management programs at facilities that manufacture, use, store, or otherwise handle regulated substances in quantities that exceed specified thresholds.

Carbon dioxide is not listed as a regulated substance.

TSCA - TOXIC SUBSTANCES CONTROL ACT: Carbon dioxide is listed on the TSCA inventory.

OSHA - OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION:

29 CFR 1910.119: Process Safety Management of Highly Hazardous Chemicals. Requires facilities to develop a process safety management program based on Threshold Quantities (TQ) of highly hazardous chemicals.

Carbon dioxide is not listed in Appendix A as a highly hazardous chemical.

STATE REGULATIONS:

CALIFORNIA:

Proposition 65: This product does NOT contain any listed substances which the State of California requires warning under this statute.

SCAQMD Rule: VOC = Not applicable

Section 4. First aid measures

Inhalation : Remove victim to fresh air and keep at rest in a position comfortable for breathing. If it is suspected that fumes are still present, the rescuer should wear an appropriate mask or self-contained breathing apparatus. If not breathing, if breathing is irregular or if respiratory arrest occurs, provide artificial respiration or oxygen by trained personnel. It may be dangerous to the person providing aid to give mouth-to-mouth resuscitation. Get medical attention. If necessary, call a poison center or physician. If unconscious, place in recovery position and get medical attention immediately. Maintain an open airway. Loosen tight clothing such as a collar, tie, belt or waistband.

Skin contact : Flush contaminated skin with plenty of water. Remove contaminated clothing and shoes. To avoid the risk of static discharges and gas ignition, soak contaminated clothing thoroughly with water before removing it. Continue to rinse for at least 10 minutes. Get medical attention. Wash clothing before reuse. Clean shoes thoroughly before reuse.

Ingestion : As this product is a gas, refer to the inhalation section.

Most important symptoms/effects, acute and delayed

Potential acute health effects

Eye contact : Contact with rapidly expanding gas may cause burns or frostbite.

Inhalation : Toxic if inhaled.

Skin contact : Contact with rapidly expanding gas may cause burns or frostbite.

Frostbite : Try to warm up the frozen tissues and seek medical attention.

Ingestion : As this product is a gas, refer to the inhalation section.

Over-exposure signs/symptoms

Eye contact : No specific data.

Inhalation : Adverse symptoms may include the following:
reduced fetal weight
increase in fetal deaths
skeletal malformations

Skin contact : Adverse symptoms may include the following:
reduced fetal weight
increase in fetal deaths
skeletal malformations

Ingestion : Adverse symptoms may include the following:
reduced fetal weight
increase in fetal deaths
skeletal malformations

Indication of immediate medical attention and special treatment needed, if necessary

Notes to physician : Treat symptomatically. Contact poison treatment specialist immediately if large quantities have been ingested or inhaled.

Specific treatments : No specific treatment.

Protection of first-aiders : No action shall be taken involving any personal risk or without suitable training. If it is suspected that fumes are still present, the rescuer should wear an appropriate mask or self-contained breathing apparatus. It may be dangerous to the person providing aid to give mouth-to-mouth resuscitation. Wash contaminated clothing thoroughly with water before removing it, or wear gloves.

See toxicological information (Section 11)

Section 2. Hazards identification

General : Read and follow all Safety Data Sheets (SDS'S) before use. Read label before use. Keep out of reach of children. If medical advice is needed, have product container or label at hand. Close valve after each use and when empty. Use equipment rated for cylinder pressure. Do not open valve until connected to equipment prepared for use. Use a back flow preventative device in the piping. Use only equipment of compatible materials of construction. Approach suspected leak area with caution.

Prevention : Never Put cylinders into unventilated areas of passenger vehicles. Obtain special instructions before use. Do not handle until all safety precautions have been read and understood. Use personal protective equipment as required. Keep away from heat, sparks, open flames and hot surfaces. - No smoking. Use only outdoors or in a well-ventilated area. Do not breathe gas. Do not eat, drink or smoke when using this product. Wash hands thoroughly after handling. Use and store only outdoors or in a well ventilated place.

Response : Get medical attention if you feel unwell. IF exposed or concerned: Get medical attention. IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing. Call a POISON CENTER or physician. Leaking gas fire: Do not extinguish, unless leak can be stopped safely. Eliminate all ignition sources if safe to do so.

Storage : Store locked up. Protect from sunlight. Protect from sunlight when ambient temperature exceeds 52°C/125°F. Store in a well-ventilated place.

Disposal : Dispose of contents and container in accordance with all local, regional, national and international regulations.

Hazards not otherwise classified : In addition to any other important health or physical hazards, this product may displace oxygen and cause rapid suffocation.

Section 3. Composition/information on ingredients

Substance/mixture : Substance

Chemical name : carbon monoxide

Other means of identification : Carbon oxide (CO); CO; Exhaust gas; Flue gas; Carbonic oxide; Carbon oxide; Carbone (oxyde de); Carbonio (ossido di); Kohlenmonoxid; Kohlenoxyd; Koolmonoxyde; NA 9202; Oxyde de carbone; UN 1016; Wegla tlenek; Carbon monooxide

CAS number/other identifiers

CAS number : 630-08-0

Product code : 001014

Ingredient name	%	CAS number
carbon monoxide	100	630-08-0

There are no additional ingredients present which, within the current knowledge of the supplier and in the concentrations applicable, are classified as hazardous to health or the environment and hence require reporting in this section.

Occupational exposure limits, if available, are listed in Section 8.

Section 4. First aid measures

Description of necessary first aid measures

Eye contact : Immediately flush eyes with plenty of water, occasionally lifting the upper and lower eyelids. Check for and remove any contact lenses. Continue to rinse for at least 10 minutes. Get medical attention.

Section 7. Handling and storage

Precautions for safe handling

Protective measures : Put on appropriate personal protective equipment (see Section 8). Contains gas under pressure. Avoid exposure - obtain special instructions before use. Avoid exposure during pregnancy. Do not handle until all safety precautions have been read and understood. Do not get in eyes or on skin or clothing. Do not breathe gas. Use only with adequate ventilation. Wear appropriate respirator when ventilation is inadequate. Do not enter storage areas and confined spaces unless adequately ventilated. Store and use away from heat, sparks, open flame or any other ignition source. Use explosion-proof electrical (ventilating, lighting and material handling) equipment. Use only non-sparking tools. Empty containers retain product residue and can be hazardous. Do not puncture or incinerate container. Use equipment rated for cylinder pressure. Close valve after each use and when empty. Protect cylinders from physical damage; do not drag, roll, slide, or drop. Use a suitable hand truck for cylinder movement.

Advice on general occupational hygiene : Eating, drinking and smoking should be prohibited in areas where this material is handled, stored and processed. Workers should wash hands and face before eating, drinking and smoking. Remove contaminated clothing and protective equipment before entering eating areas. See also Section 8 for additional information on hygiene measures.

Conditions for safe storage, including any incompatibilities : Store in accordance with local regulations. Store in a segregated and approved area. Store away from direct sunlight in a dry, cool and well-ventilated area, away from incompatible materials (see Section 10). Store locked up. Eliminate all ignition sources. Keep container tightly closed and sealed until ready for use. Cylinders should be stored upright, with valve protection cap in place, and firmly secured to prevent falling or being knocked over. Cylinder temperatures should not exceed 52 °C (125 °F).

Section 8. Exposure controls/personal protection

Control parameters

Occupational exposure limits

Ingredient name	Exposure limits
carbon monoxide	**ACGIH TLV (United States, 3/2012).** TWA: 29 mg/m³ 8 hours. TWA: 25 ppm 8 hours. **NIOSH REL (United States, 1/2013).** CEIL: 229 mg/m³ CEIL: 200 ppm TWA: 40 mg/m³ 10 hours. TWA: 35 ppm 10 hours. **OSHA PEL (United States, 6/2010).** TWA: 55 mg/m³ 8 hours. TWA: 50 ppm 8 hours. **OSHA PEL 1989 (United States, 3/1989).** CEIL: 229 mg/m³ CEIL: 200 ppm TWA: 40 mg/m³ 8 hours. TWA: 35 ppm 8 hours.

Appropriate engineering controls : Use only with adequate ventilation. Use process enclosures, local exhaust ventilation or other engineering controls to keep worker exposure to airborne contaminants below any recommended or statutory limits. The engineering controls also need to keep gas, vapor or dust concentrations below any lower explosive limits. Use explosion-proof ventilation equipment.

Section 5. Fire-fighting measures

Extinguishing media

Suitable extinguishing media : Use an extinguishing agent suitable for the surrounding fire.

Unsuitable extinguishing media : None known.

Specific hazards arising from the chemical : Contains gas under pressure. Extremely flammable gas. In a fire or if heated, a pressure increase will occur and the container may burst, with the risk of a subsequent explosion.

Hazardous thermal decomposition products : Decomposition products may include the following materials:
carbon dioxide
carbon monoxide

Special protective actions for fire-fighters : Promptly isolate the scene by removing all persons from the vicinity of the incident if there is a fire. No action shall be taken involving any personal risk or without suitable training. Contact supplier immediately for specialist advice. Move containers from fire area if this can be done without risk. Use water spray to keep fire-exposed containers cool. If involved in fire, shut off flow immediately if it can be done without risk. If this is impossible, withdraw from area and allow fire to burn. Fight fire from protected location or maximum possible distance. Eliminate all ignition sources if safe to do so.

Special protective equipment for fire-fighters : Fire-fighters should wear appropriate protective equipment and self-contained breathing apparatus (SCBA) with a full face-piece operated in positive pressure mode.

Section 6. Accidental release measures

Personal precautions, protective equipment and emergency procedures

For non-emergency personnel : Accidental releases pose a serious fire or explosion hazard. No action shall be taken involving any personal risk or without suitable training. Evacuate surrounding areas. Keep unnecessary and unprotected personnel from entering. Shut off all ignition sources. No flares, smoking or flames in hazard area. Do not breathe gas. Provide adequate ventilation. Wear appropriate respirator when ventilation is inadequate. Put on appropriate personal protective equipment.

For emergency responders : If specialised clothing is required to deal with the spillage, take note of any information in Section 8 on suitable and unsuitable materials. See also the information in "For non-emergency personnel".

Environmental precautions : Ensure emergency procedures to deal with accidental gas releases are in place to avoid contamination of the environment. Inform the relevant authorities if the product has caused environmental pollution (sewers, waterways, soil or air).

Methods and materials for containment and cleaning up

Small spill : Immediately contact emergency personnel. Stop leak if without risk. Use spark-proof tools and explosion-proof equipment.

Large spill : Immediately contact emergency personnel. Stop leak if without risk. Use spark-proof tools and explosion-proof equipment. Note: see Section 1 for emergency contact information and Section 13 for waste disposal.

Section 9. Physical and chemical properties

Burning rate	: Not applicable.
Evaporation rate	: Not available.
Flammability (solid, gas)	: Extremely flammable in the presence of the following materials or conditions: open flames, sparks and static discharge and oxidizing materials.
Lower and upper explosive (flammable) limits	: Lower: 10.9% Upper: 74.2%
Vapor pressure	: Not available.
Vapor density	: 0.97 (Air = 1)
Specific Volume (ft ^{3}/lb)	: 13.8889
Gas Density (lb/ft ^{3})	: 0.072
Relative density	: Not applicable.
Solubility	: Not available.
Solubility in water	: Not available.
Partition coefficient: n-octanol/water	: Not available.
Auto-ignition temperature	: 607°C (1124.6°F)
Decomposition temperature	: Not available.
SADT	: Not available.
Viscosity	: Not applicable.

Section 10. Stability and reactivity

Reactivity	: No specific test data related to reactivity available for this product or its ingredients.
Chemical stability	: The product is stable.
Possibility of hazardous reactions	: Under normal conditions of storage and use, hazardous reactions will not occur.
Conditions to avoid	: Avoid all possible sources of ignition (spark or flame). Do not pressurize, cut, weld, braze, solder, drill, grind or expose containers to heat or sources of ignition.
Incompatibility with various substances	: Extremely reactive or incompatible with the following materials: oxidizing materials.
Hazardous decomposition products	: Under normal conditions of storage and use, hazardous decomposition products should not be produced.
Hazardous polymerization	: Under normal conditions of storage and use, hazardous polymerization will not occur.

Section 11. Toxicological information

Information on toxicological effects

Acute toxicity

Product/ingredient name	Result	Species	Dose	Exposure
carbon monoxide	LC50 Inhalation Gas.	Rat	3760 ppm	1 hours

Irritation/Corrosion

Section 8. Exposure controls/personal protection

Environmental exposure controls	: Emissions from ventilation or work process equipment should be checked to ensure they comply with the requirements of environmental protection legislation. In some cases, fume scrubbers, filters or engineering modifications to the process equipment will be necessary to reduce emissions to acceptable levels.

Individual protection measures

Hygiene measures	: Wash hands, forearms and face thoroughly after handling chemical products, before eating, smoking and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the workstation location.
Eye/face protection	: Safety eyewear complying with an approved standard should be used when a risk assessment indicates this is necessary to avoid exposure to liquid splashes, mists, gases or dusts. If contact is possible, the following protection should be worn, unless the assessment indicates a higher degree of protection: safety glasses with side-shields.

Skin protection

Hand protection	: Chemical-resistant, impervious gloves complying with an approved standard should be worn at all times when handling chemical products if a risk assessment indicates this is necessary. Considering the parameters specified by the glove manufacturer, check during use that the gloves are still retaining their protective properties. It should be noted that the time to breakthrough for any glove material may be different for different glove manufacturers. In the case of mixtures, consisting of several substances, the protection time of the gloves cannot be accurately estimated.
Body protection	: Personal protective equipment for the body should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product. When there is a risk of ignition from static electricity, wear anti-static protective clothing. For the greatest protection from static discharges, clothing should include anti-static overalls, boots and gloves.
Other skin protection	: Appropriate footwear and any additional skin protection measures should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product.
Respiratory protection	: Use a properly fitted, air-purifying or air-fed respirator complying with an approved standard if a risk assessment indicates this is necessary. Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator.

Section 9. Physical and chemical properties

Appearance

Physical state	: Gas. [MAY BE A LIQUID AT LOW TEMPERATURE OR HIGH PRESSURE.]
Color	: Colorless.
Molecular weight	: 28.01 g/mole
Molecular formula	: C-O
Boiling/condensation point	: -191.52°C (-312.7°F)
Melting/freezing point	: -211.6°C (-348.9°F)
Critical temperature	: -140.15°C (-220.3°F)
Odor	: Odorless.
Odor threshold	: Not available.
pH	: Not available.
Flash point	: Not available.
Burning time	: Not applicable.

Section 11. Toxicological information

Potential immediate effects : Not available.

Potential delayed effects : Not available.

Long term exposure

Potential immediate effects : Not available.

Potential delayed effects : Not available.

Potential chronic health effects

Not available.

General : Causes damage to organs through prolonged or repeated exposure.

Carcinogenicity : No known significant effects or critical hazards.

Mutagenicity : No known significant effects or critical hazards.

Teratogenicity : May damage the unborn child.

Developmental effects : No known significant effects or critical hazards.

Fertility effects : May damage fertility.

Numerical measures of toxicity

Acute toxicity estimates

Not available.

Section 12. Ecological information

Toxicity

Not available.

Persistence and degradability

Not available.

Bioaccumulative potential

Not available.

Mobility in soil

Soil/water partition coefficient (K_{OC}) : Not available.

Other adverse effects : No known significant effects or critical hazards.

Section 13. Disposal considerations

Disposal methods : The generation of waste should be avoided or minimized wherever possible. Disposal of this product, solutions and any by-products should at all times comply with the requirements of environmental protection and waste disposal legislation and any regional local authority requirements. Dispose of surplus and non-recyclable products via a licensed waste disposal contractor. Waste should not be disposed of untreated to the sewer unless fully compliant with the requirements of all authorities with jurisdiction. Empty Airgas-owned pressure vessels should be returned to Airgas. Waste packaging should be recycled. Incineration or landfill should only be considered when recycling is

Section 11. Toxicological information

Not available.

Sensitization

Not available.

Mutagenicity

Not available.

Carcinogenicity

Not available.

Reproductive toxicity

Not available.

Teratogenicity

Not available.

Specific target organ toxicity (single exposure)

Not available.

Specific target organ toxicity (repeated exposure)

Name	Category	Route of exposure	Target organs
carbon monoxide	Category 1	Not determined	Not determined

Aspiration hazard

Not available.

Information on the likely routes of exposure : Not available.

Potential acute health effects

Eye contact : Contact with rapidly expanding gas may cause burns or frostbite.

Inhalation : Toxic if inhaled.

Skin contact : Contact with rapidly expanding gas may cause burns or frostbite.

Ingestion : As this product is a gas, refer to the inhalation section.

Symptoms related to the physical, chemical and toxicological characteristics

Eye contact : No specific data.

Inhalation : Adverse symptoms may include the following:
reduced fetal weight
increase in fetal deaths
skeletal malformations

Skin contact : Adverse symptoms may include the following:
reduced fetal weight
increase in fetal deaths
skeletal malformations

Ingestion : Adverse symptoms may include the following:
reduced fetal weight
increase in fetal deaths
skeletal malformations

Delayed and immediate effects and also chronic effects from short and long term exposure

Short term exposure

Section 15. Regulatory information

Clean Air Act Section 602 Class II Substances : Not listed

DEA List I Chemicals (Precursor Chemicals) : Not listed

DEA List II Chemicals (Essential Chemicals) : Not listed

SARA 302/304

Composition/information on ingredients

No products were found.

SARA 304 RQ : Not applicable.

SARA 311/312

Classification : Fire hazard
Sudden release of pressure
Immediate (acute) health hazard
Delayed (chronic) health hazard

Composition/information on ingredients

Name	%	Fire hazard	Sudden release of pressure	Reactive	Immediate (acute) health hazard	Delayed (chronic) health hazard
carbon monoxide	100	Yes.	Yes.	No.	Yes.	Yes.

State regulations

Massachusetts : This material is listed.

New York : This material is not listed.

New Jersey : This material is listed.

Pennsylvania : This material is listed.

California Prop. 65

WARNING: This product contains a chemical known to the State of California to cause birth defects or other reproductive harm.

Ingredient name	Cancer	Reproductive	No significant risk level	Maximum acceptable dosage level
carbon monoxide	No.	Yes.	No.	No.

Canada inventory : This material is listed or exempted.

International regulations

International lists : **Australia inventory (AICS)**: This material is listed or exempted.
China inventory (IECSC): This material is listed or exempted.
Japan inventory: This material is listed or exempted.
Korea inventory: This material is listed or exempted.
Malaysia Inventory (EHS Register): Not determined.
New Zealand Inventory of Chemicals (NZIoC): This material is listed or exempted.
Philippines inventory (PICCS): This material is listed or exempted.
Taiwan inventory (CSNN): Not determined.

Chemical Weapons Convention List Schedule I Chemicals : Not listed

Section 13. Disposal considerations

not feasible. This material and its container must be disposed of in a safe way. Empty containers or liners may retain some product residues. Do not puncture or incinerate container.

Section 14. Transport information

	DOT	TDG	Mexico	IMDG	IATA
UN number	UN1016	UN1016	UN1016	UN1016	UN1016
UN proper shipping name	CARBON MONOXIDE, COMPRESSED	CARBON MONOXIDE, COMPRESSED	CARBON MONOXIDE, COMPRESSED	CARBON MONOXIDE, COMPRESSED	CARBON MONOXIDE, COMPRESSED
Transport hazard class(es)	2.3 (2.1) 	2.3 (2.1) 	2.3 (2.1) 	2.3 (2.1) 	2.3 (2.1) 
Packing group	-	-	-	-	-
Environment	No.	No.	No.	No.	No.
Additional information	Inhalation hazard zone D **Limited quantity** Yes. **Packaging instruction Passenger aircraft** Quantity limitation: Forbidden. **Cargo aircraft** Quantity limitation: 25 kg **Special provisions** 4	**Explosive Limit and Limited Quantity Index** 0 **ERAP Index** 500 **Passenger Carrying Ship Index** Forbidden **Passenger Carrying Road or Rail Index** Forbidden	-	-	**Passenger and Cargo Aircraft** Quantity limitation: 0 Forbidden **Cargo Aircraft Only** Quantity limitation: Forbidden

"Refer to CFR 49 (or authority having jurisdiction) to determine the information required for shipment of the product."

Special precautions for user : **Transport within user's premises:** always transport in closed containers that are upright and secure. Ensure that persons transporting the product know what to do in the event of an accident or spillage.

Transport in bulk according to Annex II of MARPOL 73/78 and the IBC Code : Not available.

Section 15. Regulatory information

U.S. Federal regulations : **TSCA 8(a) CDR Exempt/Partial exemption**: Not determined
United States inventory (TSCA 8b): This material is listed or exempted.

Clean Air Act Section 112 (b) Hazardous Air Pollutants (HAPs) : Not listed

Clean Air Act Section 602 Class I Substances : Not listed

Section 16. Other information

History

Date of printing : 5/12/2015.

Date of issue/Date of revision : 5/12/2015.

Date of previous issue : 5/12/2015.

Version : 0.07

Key to abbreviations : ATE = Acute Toxicity Estimate
BCF = Bioconcentration Factor
GHS = Globally Harmonized System of Classification and Labelling of Chemicals
IATA = International Air Transport Association
IBC = Intermediate Bulk Container
IMDG = International Maritime Dangerous Goods
LogPow = logarithm of the octanol/water partition coefficient
MARPOL 73/78 = International Convention for the Prevention of Pollution From Ships, 1973 as modified by the Protocol of 1978. ("Marpol" = marine pollution)
UN = United NationsACGIH – American Conference of Governmental Industrial Hygienists
AIHA – American Industrial Hygiene Association
CAS – Chemical Abstract Services
CEPA – Canadian Environmental Protection Act
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act (EPA)
CFR – United States Code of Federal Regulations
CPR – Controlled Products Regulations
DSL – Domestic Substances List
GWP – Global Warming Potential
IARC – International Agency for Research on Cancer
ICAO – International Civil Aviation Organisation
Inh – Inhalation
LC – Lethal concentration
LD – Lethal dosage
NDSL – Non-Domestic Substances List
NIOSH – National Institute for Occupational Safety and Health
TDG – Canadian Transportation of Dangerous Goods Act and Regulations
TLV – Threshold Limit Value
TSCA – Toxic Substances Control Act
WEEL – Workplace Environmental Exposure Level
WHMIS – Canadian Workplace Hazardous Material Information System

References : Not available.

Indicates information that has changed from previously issued version.

Notice to reader

To the best of our knowledge, the information contained herein is accurate. However, neither the above-named supplier, nor any of its subsidiaries, assumes any liability whatsoever for the accuracy or completeness of the information contained herein.
Final determination of suitability of any material is the sole responsibility of the user. All materials may present unknown hazards and should be used with caution. Although certain hazards are described herein, we cannot guarantee that these are the only hazards that exist.

Section 15. Regulatory information

Chemical Weapons Convention List Schedule II Chemicals : Not listed

Chemical Weapons Convention List Schedule III Chemicals : Not listed

Canada

WHMIS (Canada) : Class A: Compressed gas.
Class B-1: Flammable gas.
Class D-1A: Material causing immediate and serious toxic effects (Very toxic).
Class D-2A: Material causing other toxic effects (Very toxic).
CEPA Toxic substances: This material is not listed.
Canadian ARET: This material is not listed.
Canadian NPRI: This material is listed.
Alberta Designated Substances: This material is not listed.
Ontario Designated Substances: This material is not listed.
Quebec Designated Substances: This material is not listed.

Section 16. Other information

Canada Label requirements : Class A: Compressed gas.
Class B-1: Flammable gas.
Class D-1A: Material causing immediate and serious toxic effects (Very toxic).
Class D-2A: Material causing other toxic effects (Very toxic).

Hazardous Material Information System (U.S.A.)

Caution: HMIS® ratings are based on a 0-4 rating scale, with 0 representing minimal hazards or risks, and 4 representing significant hazards or risks Although HMIS® ratings are not required on SDSs under 29 CFR 1910. 1200, the preparer may choose to provide them. HMIS® ratings are to be used with a fully implemented HMIS® program. HMIS® is a registered mark of the National Paint & Coatings Association (NPCA). HMIS® materials may be purchased exclusively from J. J. Keller (800) 327-6868.

The customer is responsible for determining the PPE code for this material.

National Fire Protection Association (U.S.A.)

Reprinted with permission from NFPA 704-2001, Identification of the Hazards of Materials for Emergency Response Copyright ©1997, National Fire Protection Association, Quincy, MA 02269. This reprinted material is not the complete and official position of the National Fire Protection Association, on the referenced subject which is represented only by the standard in its entirety.

Copyright ©2001, National Fire Protection Association, Quincy, MA 02269. This warning system is intended to be interpreted and applied only by properly trained individuals to identify fire, health and reactivity hazards of chemicals. The user is referred to certain limited number of chemicals with recommended classifications in NFPA 49 and NFPA 325, which would be used as a guideline only. Whether the chemicals are classified by NFPA or not, anyone using the 704 systems to classify chemicals does so at their own risk.

EYE CONTACT: None

SKIN CONTACT: None

CHRONIC EFFECTS: None

OTHER EFFECTS OF OVEREXPOSURE: None

EXPOSURE INFORMATION:

ROUTE OF ENTRY: Inhalation

TARGET ORGANS: None

EFFECT: Asphyxiation (suffocation)

SYMPTOMS: Exposure to an oxygen-deficient atmosphere (<19.5%) may cause dizziness, drowsiness, nausea, vomiting, excess salivation, diminished mental alertness, loss of consciousness, and death.

MEDICAL CONDITIONS AGGRAVATED BY OVEREXPOSURE: None

CARCINOGENIC POTENTIAL: Hydrogen is not listed by NTP, OSHA or IARC.

SECTION 4. FIRST AID

INHALATION: Persons suffering from lack of oxygen should be removed to fresh air. If victim is not breathing, administer artificial respiration. If breathing is difficult, administer oxygen. Obtain prompt medical attention.

SKIN CONTACT: None

EYE CONTACT: None

INGESTION: None

NOTES TO PHYSICIAN: None

SECTION 5. FIRE AND EXPLOSION

FLASH POINT:	AUTOIGNITION:	FLAMMABLE LIMITS:
Flammable gas	565.5_C (1050_F)	**LOWER:** 4% **UPPER:** 74%

EXTINGUISHING MEDIA: CO_2, dry chemical, water spray or fog for surrounding area. Do not extinguish until hydrogen source is shut off.

HAZARDOUS COMBUSTION PRODUCTS: None

SPECIAL FIRE FIGHTING INSTRUCTIONS: Evacuate all personnel from danger area. Immediately cool container with water spray from maximum distance, taking care not to extinguish flames. If flames are accidentally extinguished, explosive re-ignition may occur. Stop flow of gas if without risk while continuing cooling water spray.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Burns with a pale blue, nearly invisible flame. Hydrogen is easily ignited with low-ignition energy, including static electricity. Hydrogen is lighter than air and can accumulate in the upper sections of enclosed spaces. Pressure in a container can build up due to heat, and it may rupture if pressure relief devices should fail to function.

SECTION 6. ACCIDENTAL RELEASE MEASURES

Evacuate immediate area. Eliminate any possible sources of ignition, and provide maximum explosion-proof ventilation. Shut off source of hydrogen, if possible. If leaking from cylinder, or valve, call the Air Products' emergency phone number. The presence of a hydrogen flame can be detected by approaching cautiously with an outstretched straw broom to make the flame visible.

AIR PRODUCTS

MATERIAL SAFETY DATA SHEET

SECTION 1. PRODUCT IDENTIFICATION

PRODUCT NAME: **Hydrogen, compressed**
CHEMICAL NAME: Hydrogen **FORMULA:** H_2
SYNONYMS: None
MANUFACTURER: **Air Products and Chemicals, Inc.**
7201 Hamilton Boulevard
Allentown, PA 18195-1501
PRODUCT INFORMATION: 1-800-752-1597
MSDS NUMBER: 1009 **REVISION:** 4
REVISION DATE: June 1994

SECTION 2. COMPOSITION/INFORMATION ON INGREDIENTS

Hydrogen is sold as pure product >99%

CAS NUMBER: 1333-74-0

EXPOSURE LIMITS:
OSHA: None **ACGIH:** Simple asphyxiant

SECTION 3. HAZARD IDENTIFICATION

EMERGENCY OVERVIEW

Hydrogen is a flammable, colorless, odorless, compressed gas packaged in cylinders at high pressure. It poses an immediate fire and explosive hazard when concentrations exceed 4%. It is much lighter than air and burns with an invisible flame. High concentrations that will cause suffocation are within the flammable range and must not be entered.

EMERGENCY TELEPHONE NUMBERS

(800) 523-9374 Continental U.S., Canada, and Puerto Rico
(610) 481-7711 other locations

POTENTIAL HEALTH EFFECTS INFORMATION:

INHALATION: Asphyxiant. It should be noted that before suffocation could occur, the lower flammability limit of hydrogen in air would be exceeded possibly causing both an oxygen-deficient and explosive atmosphere. Exposure to moderate concentrations may cause dizziness, headache, nausea and unconsciousness. Exposure to atmospheres containing 8-10% or less oxygen will quickly bring about unconsciousness without warning leaving individuals unable to protect themselves. Lack of sufficient oxygen may cause serious injury or death.

SECTION 7. HANDLING AND STORAGE

STORAGE: Specific requirements are listed in NFPA 50A. Cylinder storage locations should be well-protected, well-ventilated, dry, and separated from combustible materials. Cylinders should never knowingly be allowed to reach a temperature exceeding 125 _F (52 _C). Cylinders of hydrogen should be separated from oxygen cylinders or other oxidizers by a minimum distance of 20 ft., or by a barrier of noncombustible material at least 5 ft. high having a fire resistance rating of at least _ hour.

Cylinders should be stored upright with valve protection cap in place and firmly secured to prevent falling or being knocked over. Protect cylinders from physical damage; do not drag, roll, slide or drop. Use a suitable hand truck for cylinder movement. Post "No Smoking or Open Flames" signs in the storage areas. There should be no sources of ignition. All electrical equipment should be explosion proof in the storage and use areas. Storage areas must meet national electric codes for class 1 hazardous areas.

HANDLING: Do not "open" hydrogen cylinder valve before connecting it, since self-ignition may occur. Hydrogen is the lightest gas known and may collect in the top of buildings with out proper ventilation. It may leak out of a system which is gas-tight for air or other gases. Leak check system with leak detection solution, never with flame. If user experiences difficulty operating cylinder valve, discontinue use and contact supplier. Use only approved CGA connections. DO NOT USE ADAPTERS. Never insert an object (e.g., wrench, screwdriver, pry bar, etc.) into valve cap openings. Doing so may damage valve, causing a leak to occur. Use an adjustable strap wrench to remove over-tight or rusted caps. Never strike an arc on a compressed gas cylinder or make a cylinder a part of an electrical circuit.

SPECIAL PRECAUTIONS: Use piping and equipment adequately designed to withstand pressures to be encountered. Use a check valve or other protective apparatus in any line or piping from the cylinder to prevent reverse flow.

SECTION 8. PERSONAL PROTECTION/EXPOSURE CONTROLS

ENGINEERING CONTROLS: Provide natural or explosion-proof ventilation adequate to ensure hydrogen does not reach its lower explosive limit of 4%.

RESPIRATORY PROTECTION:

General Use: None

Emergency Use: Air supplied respirators are required in oxygen-deficient atmospheres. Before entering area you must check for flammable or oxygen-deficient atmospheres.

PROTECTIVE GLOVES: Work gloves are recommended when handling cylinders.

EYE PROTECTION: Safety glasses are recommended when handling cylinders.

OTHER PROTECTIVE EQUIPMENT: Safety shoes are recommended when handling cylinders.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE AND STATE: Colorless gas at normal temperature and pressure.

ODOR: Odorless

MOLECULAR WEIGHT: 2.016

BOILING POINT (1 atm): -423.0 _F (-252.8 _C)

SPECIFIC GRAVITY (Air =1): 0.06960

FREEZING POINT/MELTING POINT: -434.5 °F (-259.2 _C)

VAPOR PRESSURE (at 70 °F): Not applicable

GAS DENSITY (At 70_F (21.1_C) and 1 atm): 0.00521 lb/ft^3 (0.08342 kg/m^3)

SOLUBILITY IN WATER (Vol/Vol at 60_ F (15.6_C)): 0.019

SPECIFIC VOLUME (At 70_F (21.1_C) and 1 atm): 192 ft^3/lb (11.99m^3/kg)

SECTION 10. REACTIVITY/STABILITY

CHEMICAL STABILITY: Stable

CONDITIONS TO AVOID: None

INCOMPATIBILITY (Materials to Avoid): Oxidizing agents. Some steels are susceptible to hydrogen embrittlement at high pressures and temperatures.

REACTIVITY:

A) **HAZARDOUS DECOMPOSITION PRODUCTS:** None
B) **HAZARDOUS POLYMERIZATION:** Will not occur.

SECTION 11. TOXICOLOGICAL INFORMATION

Hydrogen is a simple asphyxiant.

SECTION 12. ECOLOGICAL INFORMATION

No adverse ecological effects are expected. Hydrogen does not contain any Class I or Class II ozone depleting chemicals (40 CFR Part 82). Hydrogen is not listed as a marine pollutant by DOT (49 CFR Part 171).

SECTION 13. DISPOSAL

WASTE DISPOSAL METHOD: Do not attempt to dispose of residual or unused product in the cylinder. Return to supplier for safe disposal.

Residual product within process system may be vented at a controlled rate, to the atmosphere through a vent stack that discharges to an elevated point. This stack should be in an isolated area away from ignition sources.

SECTION 14. TRANSPORTATION

DOT/IMO SHIPPING NAME: Hydrogen, compressed

HAZARD CLASS: 2.1 (Flammable Gas)

IDENTIFICATION NUMBER: UN1049

PRODUCT RQ: None

SHIPPING LABEL(s): Flammable gas.

PLACARD (When required): Flammable gas.

SPECIAL SHIPPING INFORMATION: Cylinder should be transported in a secure upright position in a well ventilated truck. NEVER TRANSPORT IN PASSENGER COMPARTMENT OF A VEHICLE.

Shipment of compressed gas cylinders which have not been filled with the owner's consent is a violation of Federal law (49 CFR Part 173.301 (b)).

SECTION 15. REGULATORY INFORMATION

U.S. FEDERAL REGULATIONS:

EPA - ENVIRONMENTAL PROTECTION AGENCY

CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (40 CFR Parts 117 and 302):

Reportable Quantity (RQ): None

THE DOW CHEMICAL COMPANY

MATERIAL SAFETY DATA SHEET

Product Name: MONOETHANOLAMINE
MSDS#: 1592

Effective Date: 06/17/2003
Page 1 of 17

Dow (hereinafter, and for purposes of this MSDS only, refers to The Dow Chemical Company and to Dow Chemical Canada Inc.) encourages and expects you to read and understand the entire MSDS, as there is important information throughout the document. Dow expects you to follow the precautions identified in this document unless your use conditions would necessitate other appropriate methods or actions.

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

1.1 IDENTIFICATION

Product Name MONOETHANOLAMINE

1.2 COMPANY IDENTIFICATION

The Dow Chemical Company
Midland, MI 48674

1.3 EMERGENCY TELEPHONE NUMBER

24-HOUR EMERGENCY TELEPHONE NUMBER: (989)636-4400.
Customer Information Number: 1-800-258-2436.

SARA: Superfund Amendment and Reauthorization Act

SECTION 302/304: Requires emergency planning on threshold planning quantities (TPQ) and release reporting based on reportable quantities (RQ) of EPA's extremely hazardous substances (40 CFR Part 355).

Extremely Hazardous Substances: None

Threshold Planning Quantity (TPQ): None

SECTIONS 311/312: Require submission of material safety data sheets (MSDSs) and chemical inventory reporting with identification of EPA defined hazard classes (40 CFR Part 370). The hazard classes for this product are:

IMMEDIATE:	No	PRESSURE:	Yes
DELAYED:	No	REACTIVITY:	No
		FLAMMABLE:	Yes

SECTION 313: Requires submission of annual reports of release of toxic chemicals that appear in 40 CFR Part 372.

Hydrogen does not require reporting under Section 313

40 CFR PART 68: Risk Management for Chemical Accidental Release. Requires the development and implementation of risk management programs at facilities that manufacture, use, store, or otherwise handle regulated substances in quantities that exceed specified thresholds.

Hydrogen is not listed as a regulated substance. However, any process that involves a flammable gas on site in one location, in quantities of 10,000 pounds (4,553 kg) or greater, is covered under this regulation.

TSCA: Toxic Substance Control Act: Hydrogen is listed on the TSCA inventory.

OSHA - OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION:

29 CFR 1910.119: Process Safety Management of Highly Hazardous Chemicals. Requires facilities to develop a process safety management program based on Threshold Quantities (TQ) of highly hazardous chemicals.

Hydrogen is not listed in Appendix A as a highly hazardous chemical. However, any process that involves a flammable gas on site in one location, in quantities of 10,000 pounds (4,553 kg) or greater is covered under this regulation unless it is used as fuel.

SECTION 16. OTHER INFORMATION

OTHER INFORMATION:

NFPA RATINGS:		**HMIS RATINGS:**	
HEALTH:	= 0	HEALTH:	= 0
FLAMMABILITY:	= 4	FLAMMABILITY:	= 4
REACTIVITY:	= 0	REACTIVITY:	= 0
SPECIAL:	= SA (CGA recommends this to designate simple asphyxiant)		

2. COMPOSITION INFORMATION

Component	CAS #	Amount (%W/W)
Monoethanolamine	141-43-5	>= 99.5 %

3. HAZARDS IDENTIFICATION

3.1 EMERGENCY OVERVIEW

Appearance Colorless

Physical State Liquid

Odor Ammoniacal

Hazards of product

CAUSES EYE AND SKIN BURNS.
HARMFUL IF INHALED OR ABSORBED THROUGH SKIN.
HARMFUL IF SWALLOWED.
EVACUATE AREA.
KEEP UPWIND OF SPILL.

ASPIRATION MAY CAUSE LUNG DAMAGE.
REPEATED EXPOSURE MAY CAUSE LIVER AND KIDNEY DAMAGE.

3.2 POTENTIAL HEALTH EFFECTS

Effects of Single Acute Overexposure

Inhalation May cause irritation of the respiratory tract, experienced as nasal discomfort and discharge, coughing, and possibly accompanied by chest pain. Prolonged overexposure may cause injury to the respiratory tract.

Eye Contact Liquid causes severe irritation, experienced as discomfort or pain, excess blinking and tear production, marked excess redness and swelling of the conjunctiva, and chemical burns of the cornea.

Skin Contact Causes local discomfort or pain, severe excess redness and swelling, tissue destruction, fissures, ulceration, and possibly bleeding into the injured area.

Skin Absorption Toxic. Prolonged or widespread contact may result in the absorption of potentially harmful amounts of material.

Swallowing Aspiration into the lungs may occur during ingestion or vomiting, resulting in lung injury. Causes severe irritation or chemical burns of the mouth, throat, esophagus, and stomach, with pain or discomfort in the mouth, throat, chest, and abdomen, nausea, vomiting, diarrhea, dizziness, drowsiness, thirst, faintness, weakness, circulatory collapse, and coma.

Chronic, Prolonged or Repeated Overexposure

Effects of Repeated Overexposure Repeated overexposure may cause damage to kidneys and liver.
Other Effects of Overexposure None currently known.

Medical Conditions Aggravated by Exposure

Skin contact may aggravate an existing dermatitis. Inhalation of material may aggravate asthma and inflammatory or fibrotic pulmonary disease.

See Section 11 for toxicological information and additional information about potential health effects.

3.3 POTENTIAL ENVIRONMENTAL EFFECTS

See Section 12 for Ecological Information.

4. FIRST AID PROCEDURES

4.1 INHALATION

Remove to fresh air. Give artificial respiration if not breathing. If breathing is difficult, oxygen may be given by qualified personnel. Obtain medical attention.

4.2 EYE CONTACT

Immediately flush eyes with water and continue washing for at least 15 minutes. DO NOT remove contact lenses, if worn. Obtain medical attention without delay, preferably from an ophthalmologist.

4.3 SKIN CONTACT

Immediately remove contaminated clothing and shoes. Wash skin with soap and water. Obtain medical attention. Wash clothing before reuse. Discard contaminated leather articles such as shoes and belt.

4.4 SWALLOWING

If patient is fully conscious, give two glasses of milk or water at once. DO NOT INDUCE VOMITING. Obtain medical attention without delay.

4.5 NOTES TO PHYSICIAN

There is no specific antidote. Treatment of overexposure should be directed at the control of symptoms and the clinical condition of the patient.
The hazards of this material are due mainly to its severely irritant properties on skin and mucosal surfaces.
Due to the irritant nature of the material, the stomach should be evacuated carefully in cases of poisoning by swallowing.

5. FIRE FIGHTING MEASURES

5.1 FLAMMABLE PROPERTIES - REFER TO SECTION 9, PHYSICAL AND CHEMICAL PROPERTIES

5.2 EXTINGUISHING MEDIA

Extinguish fires with water spray or apply alcohol-type or all-purpose-type foam by manufacturer's recommended techniques for large fires. Use carbon dioxide or dry chemical media for small fires.

5.3 FIRE FIGHTING PROCEDURES

Do not direct a solid stream of water or foam into burning molten material; this may cause spattering and spread the fire.

5.4 SPECIAL PROTECTIVE EQUIPMENT FOR FIREFIGHTERS

Use self-contained breathing apparatus, eye protection, and protective clothing.

5.5 UNUSUAL FIRE AND EXPLOSION HAZARDS

During fire, oxides of nitrogen may be evolved.
See Section 8.3 - Engineering Controls

5.6 HAZARDOUS COMBUSTION PRODUCTS

Burning can produce the following products: Oxides of carbon and nitrogen. Carbon monoxide is highly toxic if inhaled; carbon dioxide in sufficient concentrations can act as an asphyxiant. Acute overexposure to the products of combustion may result in irritation of the respiratory tract.

6. ACCIDENTAL RELEASE MEASURES

Steps to be Taken if Material is Released or Spilled:
Contain spilled material if possible. Collect in suitable and properly labeled containers. See Section 13, Disposal Considerations, for additional information.

Personal Precautions: Evacuate area. Refer to Section 7, Handling for additional precautionary measures. Keep upwind of spill. Ventilate area of leak or spill. Only trained and properly protected personnel must be involved in clean-up operations.

Environmental Precautions: Prevent from entering into soil, ditches, sewers, waterways and/or groundwater. See Section 12, Ecological Information.

7. HANDLING AND STORAGE

7.1 HANDLING

General Handling
Do not get in eyes, on skin, on clothing.
Avoid breathing vapor.
Do not swallow.
Wash thoroughly after handling.
Keep container closed.
Use with adequate ventilation.
Do not use sodium nitrite or other nitrosating agents in formulations containing this product.
Suspected cancer-causing nitrosamines could be formed.
See Section 8, EXPOSURE CONTROLS AND PERSONAL PROTECTION.

Ventilation
Provide general and/or local exhaust ventilation to control airborne levels below the exposure guidelines.

7.2 STORAGE

STABILITY - Monoethanolamine and iron form a complex molecule, trisethanolamino-iron. This material can spontaneously decompose at temperatures between 130° and 160°C, and has

been suspected of causing a fire in a nearly empty storage tank containing a 'heel' of MEA in contact with carbon steel steam coils. If steam coil heating is used, low pressure steam in stainless steel coils is preferred. Since this same mechanism may occur in drums, take care when thawing drummed MEA with heating coils and maintain temperature below 130°C.

8. EXPOSURE CONTROLS AND PERSONAL PROTECTION

8.1 EXPOSURE LIMITS

Component	Exposure Limits	Skin	Form
Monoethanolamine	3 ppm TWA8 ACGIH 6 ppm STEL ACGIH 3 ppm TWA8 OSHA 6 mg/m3 TWA8 OSHA		

In the Exposure Limits Chart above, if there is no specific qualifier (i.e., Aerosol) listed in the Form Column for a particular limit, the listed limit includes all airborne forms of the substance that can be inhaled.

A "Yes" in the Skin Column indicates a potential significant contribution to overall exposure by the cutaneous (skin) route, including mucous membranes and the eyes, either by contact with vapors or by direct skin contact with the substance. A "Blank" in the Skin Column indicates that exposure by the cutaneous (skin) route is not a potential significant contributor to overall exposure.

8.2 PERSONAL PROTECTION

Respiratory Protection: Atmospheric levels should be maintained below the exposure guideline.
When airborne exposure guidelines and/or comfort levels may be exceeded, use an approved air-purifying respirator.
For emergency response or for situations where the atmospheric level is unknown, use an approved positive-pressure self-contained breathing apparatus or positive-pressure airline with auxiliary self-contained air supply.

Ventilation: Provide general and/or local exhaust ventilation to control airborne levels below the exposure guidelines.

Eye Protection: Monogoggles.

Protective Gloves: Polyvinyl chloride coated
Rubber.

Other Protective Equipment: Eye bath, safety shower, and chemical apron.

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical State: Liquid

Appearance: Colorless

Odor: Ammoniacal

Flash Point - Closed Cup: **96 °C 205 °F** *Pensky-Martens Closed Cup ASTM D 93*

Flash Point - Open Cup: **104 °C 220 °F** *Cleveland Open Cup ASTM D 92*

Flammable Limits In Air:
Lower *No test data available.*
Upper *No test data available.*

Autoignition Temperature: *No test data available.*

Vapor Pressure: **0.2 mmHg** *20 °C*

Boiling Point (760 mmHg): **170 °C 339 °F**

Vapor Density (air = 1): **2.1**

Specific Gravity (H2O = 1): **1.017** *20 °C / 20 °C*

Freezing Point: **11 °C 51 °F**

Melting Point: *Not applicable.*

Solubility in Water (by weight): **100 %** *20 °C*

pH: *No test data available.*

Molecular Weight: **61 g/mol**

Octanol/Water Partition Coefficient - Measured: **-1.31**

Evaporation Rate (Butyl Acetate = 1): **0.02**

Percent Volatiles: **100 Wt%**

10. STABILITY AND REACTIVITY

10.1 STABILITY/INSTABILITY Stable.

Conditions to Avoid: Temperatures above 250 degrees C. May undergo self-sustaining thermal decomposition. See Section 7.2 for additional information on storage stability.

Incompatible Materials: Strong oxidizing agents. Strong bases. Strong acids. Aldehydes. Ketones. Acrylates. Organic anhydrides. Organic halides. Formates. Lactones. Oxalates.

10.2 HAZARDOUS POLYMERIZATION Will not occur.

11. TOXICOLOGICAL INFORMATION

The following information is applicable to monoethanolamine.

ACUTE TOXICITY

Peroral

Rat; male; LD50 = 1.19 (0.79 - 1.80) ml/kg; slope = 3.84

Time to Death: 0 to 12 days.

Peroral

Rat; female; LD50 = 1.07 (0.72 - 1.59) ml/kg; slope = 4.96

Time to Death: 0 to 12 days.

Peroral

Combined effects for males and females:

Major Signs: sluggishness, lacrimation, piloerection, kyphosis, unsteady gait, emaciation, pallor, red or brown discharge on perianal, periocular, and perigenital fur.

Gross Pathology: lungs, kidneys, stomachs, and intestines discolored; liver and stomach adhesions; stomachs gas- or liquid-filled.

Percutaneous

Rabbit; male; LD50 = 2.46 (1.76 - 3.39) ml/kg; slope = 5.60; 24 h occluded.

Time to Death: 1 to 13 days.

Percutaneous

Rabbit; female; LD50 = 2.83 (1.61 - 4.98) ml/kg; slope = 3.89; 24 h occluded.

Time to Death: 1 to 13 days.

Percutaneous

Combined effects for males and females:

Major Signs: sluggishness, audible breathing in one, abdominal distention, prostration in one, emaciation.

Irritation: erythema, edema, ecchymosis, necrosis, ulceration, desquamation, alopecia on one.

Gross Pathology: numerous organs discolored, hemorrhaged intestines, stomachs and intestines liquid- or gas-filled.

Inhalation

Substantially saturated vapor studies, 6 hour exposure static generation method Rat; male and female

Mortality: 0/5

Gross Pathology: Nothing remarkable.

IRRITATION

Skin: Rabbit; 4-hour occluded contact; 0.5 ml
Results: severe erythema, edema and necrosis with subsequent ulceration and scabbing, severe irritation persisted through 14 days.
Skin: Rabbit; 4 h occluded
Results: corrosive

Eye: Rabbit; 0.005 ml
Results: severe corneal injury with vascularization and corneal deformation, severe iritis, severe conjunctival irritation with necrosis and hemorrhages, healed by 21 days.

REPEATED EXPOSURE

In an inhalation study with rats, guinea pigs, and dogs presented in the literature, doses varied up to 102 ppm over durations ranging from 3.5-13 wks for rats, 3.5 wks for guinea pigs, and 4-13 wks for dogs. Major signs at high exposures included mortality, severe stress, breathing difficulties, and behavior changes. Histopathological changes were observed in lungs and nasal mucosa in guinea pigs and in livers and kidneys in guinea pigs and dogs. All exposure levels showed skin histopathology.
In an inhalation study with rats at doses up to 160 ppm for up to 6 months presented in literature, major signs included decreased body weights, altered hematological parameters, altered urine chemistries, and altered hippuric acid synthesis. The study concluded that the liver and kidney are the target organs.
In a 4-week dietary study with rats at doses of up to 2670 mg/kg/day, the major signs at 1280 mg/kg/day were deaths, kidney and liver histopathology. Altered liver and kidney weights were observed at 640 mg/kg/day.

SENSITIZATION (ANIMAL AND HUMAN STUDIES)

A repeated insult patch test was carried out on human volunteers. No skin reaction was observed.

DEVELOPMENTAL TOXICITY

In a developmental study with rats reported in literature, doses of up to 450 mg/kg were administered by gavage. Significant reductions in food consumption and body weight were observed in the 450 mg/kg group. The NOEL was 120 mg/kg/day for maternal toxicity and greater than 450 mg/kg/day for embryofetal toxicity and teratogenicity. No increases in malformation rate or growth retardation were observed in fetuses or pups, indicating that MEA was not embryotoxic or teratogenic in the rat following gavage exposure., In a cutaneous study with rats, doses of up to 225 mg/kg were administered. Severe skin irritation or lesions and a significant decrease in body weight gain were observed at 225 mg/kg/day. The NOEL was 75/mg/kg/day for maternal toxicity and greater than 225 mg/kg/day for embryofetal toxicity and teratogenicity. A study with rabbits had similar results. The NOEL was 25 mg/kg/day for maternal toxicity and greater than 75 mg/kg/day for embryofetal toxicity and teratogenicity.

GENETIC TOXICOLOGY

In Vitro
This material was not genotoxic in various mutagenicity and clastogenicity tests.

In Vivo
This material was not genotoxic in various mutagenicity and clastogenicity tests.

PHARMACOKINETICS AND METABOLISM

In Vivo
As reported in the literature, the fate of ethanolamine-1, 2-C14 in the intact rat, tissue slices, and homogenates resulted in 54% of the dose in the liver, spleen, kidneys, heart, brain, and diaphram and 11.5% as CO2, 8 hr after intraperitoneal administration. The liver was the most active tissue followed by the heart and brain. MEA is incorporated into the liver phosphatidylethanolamines via phosphorylethanolamine and CDP-ethanolamine (cytidine-5'-diphosphoethanolamine).

SIGNIFICANT DATA WITH POSSIBLE RELEVANCE TO HUMANS

Inhalation studies of monoethanolamine (MEA) in laboratory animals produced effects which suggest possible injury to the nervous system. A laboratory study suggests that rats given high doses of MEA by gavage produced increased embryofetal death, growth retardation and some malformations (hydronephrosis/hydroureter). Due to the high doses used and other technical deficiencies, the validity of this study is somewhat questionable. There is evidence that no embryofetotoxicity or teratogenicity was produced in rats or rabbits when MEA was administered by skin contact, a more relevant route of potential human exposure.

12. ECOLOGICAL INFORMATION

12.1 ENVIRONMENTAL FATE

The following information is applicable to monoethanolamine.
BOD (% Oxygen consumption)

	Day 5	Day 10	Day 15	Day 20	Day 28/30
	60 %	75 %		100 %	

BOD (% Oxygen consumption)

	Day 5	Day 10	Day 15	Day 20	Day 28/30
	52 %	73 %		90 %	

12.2 ECOTOXICITY

Toxicity to Micro-organisms
Bacterial Inhibition; IC50
Result value: 700 mg/L

Toxicity to Micro-organisms
Bacterial Inhibition; IC50
Result value: > 2000 mg/L

Toxicity to Aquatic Invertebrates
Daphnia; 48 h; LC50
Result value: 33 mg/L

Toxicity to Aquatic Invertebrates
Daphnia; 48 h; LC50
Result value: 93 mg/L

Toxicity to Fish
Fathead Minnow; 96 h; LC50
Result value: 125 mg/L

Toxicity to Fish
Fathead Minnow; 96 h; LC50
Result value: 206 mg/L

12.3 FURTHER INFORMATION

THODCARB
Theoretical Oxygen Demand (THOD) - calculated:: 1.31 mg/mg

THODNITR
Theoretical Oxygen Demand (THOD) - calculated:: 0.79 mg/mg

Chemical Oxygen Demand (COD) - measured: 1.54 mg/mg

Octanol/Water Partition Coefficient - Measured: -1.31

13. DISPOSAL CONSIDERATIONS

13.1 DISPOSAL

DO NOT DUMP INTO ANY SEWERS, ON THE GROUND, OR INTO ANY BODY OF WATER. All disposal practices must be in compliance with all Federal, State/Provincial and local laws and regulations. Regulations may vary in different locations. Waste characterizations and compliance with applicable laws are the responsibility solely of the waste generator. DOW HAS NO CONTROL OVER THE MANAGEMENT PRACTICES OR MANUFACTURING PROCESSES OF PARTIES HANDLING OR USING THIS MATERIAL. THE INFORMATION PRESENTED HERE PERTAINS ONLY TO THE PRODUCT AS SHIPPED IN ITS INTENDED CONDITION AS DESCRIBED IN MSDS SECTION 2 (Composition/ Information on Ingredients). FOR UNUSED & UNCONTAMINATED PRODUCT, the preferred options include sending to a licensed, permitted: incinerator or other thermal destruction device. As a service to its customers, Dow can provide names of information resources to help identify waste management companies and other facilities which recycle, reprocess or manage chemicals or plastics, and that manage used drums. Telephone Dow's Customer Information Group at 1-800-258-2436 or 1-989-832-1556 (U.S.), or 1-800-331-6451 (Canada) for further details .

14. TRANSPORT INFORMATION

14.1 U.S. D.O.T.

NON-BULK
Proper Shipping Name : ETHANOLAMINE
Hazard Class : 8.
ID Number : UN2491
Packing Group : PG III

BULK
Proper Shipping Name : ETHANOLAMINE
Hazard Class : 8.
ID Number : UN2491
Packing Group : PG III

This information is not intended to convey all specific regulatory or operational requirements/information relating to this product. Additional transportation system information can be obtained through an authorized sales or customer service representative. It is the responsibility of the transporting organization to follow all applicable laws, regulations and rules relating to the transportation of the material.

15. REGULATORY INFORMATION

15.1 FEDERAL/NATIONAL

OSHA HAZARD COMMUNICATION STANDARD

This product is a "Hazardous Chemical" as defined by the OSHA Hazard Communication Standard, 29 CFR 1910.1200.

SUPERFUND AMENDMENTS AND REAUTHORIZATION ACT OF 1986 TITLE III (EMERGENCY PLANNING AND COMMUNITY RIGHT TO KNOW ACT) SECTION 313

To the best of our knowledge this product does not contain chemicals at levels which require reporting under this statute.

SUPERFUND AMENDMENTS AND REAUTHORIZATION ACT OF 1986 TITLE III (EMERGENCY PLANNING AND COMMUNITY RIGHT TO KNOW ACT)SECTIONS 311 AND 312

Delayed (Chronic) Health Hazard : Yes
Fire Hazard : No
Immediate (Acute) Health Hazard : Yes
Reactive Hazard : No
Sudden Release of Pressure Hazard : No

CEPA - DOMESTIC SUBSTANCES LIST (DSL)

All substances contained in this product are listed on the Canadian Domestic Substances List (DSL) or are not required to be listed.

TOXIC SUBSTANCES CONTROL ACT (TSCA)

All components of this product are on the TSCA Inventory or are exempt from TSCA Inventory requirements.

15.2 STATE/LOCAL

PENNSYLVANIA (WORKER AND COMMUNITY RIGHT TO KNOW ACT): PENNSYLVANIA HAZARDOUS SUBSTANCES LIST AND/OR PENNSYLVANIA ENVIRONMENTAL HAZARDOUS SUBSTANCE LIST:

The following product components are cited in the Pennsylvania Hazardous Substance List and/or the Pennsylvania Environmental Substance List, and are present at levels which require reporting.

Component	CAS #	Amount
Monoethanolamine	141-43-5	< 100.0000%

PENNSYLVANIA (WORKER AND COMMUNITY RIGHT TO KNOW ACT): PENNSYLVANIA SPECIAL HAZARDOUS SUBSTANCES LIST:

To the best of our knowledge this product does not contain chemicals at levels which require reporting under this statute.

CALIFORNIA PROPOSITION 65 (SAFE DRINKING WATER AND TOXIC ENFORCEMENT ACT OF 1986)

This product contains no listed substances known to the State of California to cause cancer, birth defects or other reproductive harm, at levels which would require a warning under the statute.

CALIFORNIA SCAQMD RULE 443.1 (SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT RULE 443.1, LABELING OF MATERIALS CONTAINING ORGANIC SOLVENTS)

VOC: Vapor pressure 0.2 mmHg @ 20° C
1014 g/l VOC
1016 g/l less water and less exempted solvents

This section provides selected regulatory information on this product including its components. This is not intended to include all regulations. It is the responsibility of the user to know and comply with all applicable rules, regulations and laws relating to the product being used.

16. OTHER INFORMATION

16.1 ADDITIONAL INFORMATION

ADDITIONAL INFORMATION: Additional product safety information on this product may be obtained by calling Dow's Customer Information Group at 1-800-258-2436 (U.S.) or 1-800-331-6451 (Canada).
Ask for the brochure:
Ethanolamines (Family Brochure)
Ethanolamines Storage and Handling (Brochure)

16.2 HAZARD RATING SYSTEM

NFPA ratings for this product are: H - 3 **F -** 1 **R -** 0

These ratings are part of a specific hazard communication program and should be disregarded where individuals are not trained in the use of this hazard rating system. You should be familiar with the hazard communication programs applicable to your workplace.

16.3 RECOMMENDED USES AND RESTRICTIONS

FOR INDUSTRY USE ONLY

16.4 REVISION

Version: 5.
Revision: 06/17/2003
Most recent revision(s) are noted by the bold, double bars in left-hand margin throughout this document.

16.5 LEGEND

Bacterial/NA	Non Acclimated Bacteria
F	Fire
H	Health
IHG	Industrial Hygiene Guideline
N/A	Not available
NFPA	National Fire Protection Association
O	Oxidizer
R	Reactivity
TS	Trade secret

TARGET ORGANS: None
MEDICAL CONDITIONS AGGRAVATED BY OVEREXPOSURE: None
CARCINOGENICITY: Methane is not listed as a carcinogen or potential carcinogen by NTP, IARC, or OSHA Subpart Z.

SECTION 4. FIRST AID MEASURES

EYE CONTACT: No treatment necessary.
INGESTION: Not applicable
INHALATION: Remove person to fresh air. If not breathing, administer artificial respiration. If breathing is difficult, administer oxygen. Obtain prompt medical attention.
SKIN CONTACT: No treatment necessary.
NOTES TO PHYSICIAN: Treatment of overexposure should be directed at the control of symptoms and the clinical condition.

SECTION 5. FIRE FIGHTING MEASURES

FLASH POINT:	AUTOIGNITION:	FLAMMABLE RANGE:
-306 °F (-187.8 °C)	999 °F (537 °C)	5.0% - 15%

EXTINGUISHING MEDIA: Dry chemical, carbon dioxide, or water.
SPECIAL FIRE FIGHTING INSTRUCTIONS: Evacuate all personnel from area. If possible, without risk, shut off source of methane, then fight fire according to types of materials burning. Extinguish fire only if gas flow can be stopped. This will avoid possible accumulation and re-ignition of a flammable gas mixture. Keep adjacent cylinders cool by spraying with large amounts of water until the fire burns itself out. Self-contained breathing apparatus (SCBA) may be required.
UNUSUAL FIRE AND EXPLOSION HAZARDS: Most cylinders are designed to vent contents when exposed to elevated temperatures. Pressure in a cylinder can build up due to heat and it may rupture if pressure relief devices should fail to function.
HAZARDOUS COMBUSTION PRODUCTS: Carbon monoxide

SECTION 6. ACCIDENTAL RELEASE MEASURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED: Evacuate immediate area. Eliminate any possible sources of ignition, and provide maximum explosion-proof ventilation. Use a flammable gas meter (explosimeter) calibrated for Methane to monitor concentration. Never enter an area where Methane concentration is greater than 1.0% (which is 20% of the lower flammable limit). An immediate fire and explosion hazard exists when atmospheric Methane concentration exceeds 5.0%. Use appropriate protective equipment (SCBA and fire resistant suit). Shut off source of leak if possible. Isolate any leaking cylinder. If leak is from container, pressure relief device or its valve, contact your supplier. If the leak is in the user's system, close the cylinder valve, safely vent the pressure, and purge with an inert gas before attempting repairs.

SECTION 7. STORAGE AND HANDLING

STORAGE: Store cylinders in a well-ventilated, secure area, protected from the weather. Cylinders should be stored upright with valve outlet seals and valve protection caps in place. There should be no sources of ignition. All electrical equipment should be explosion-proof in the storage areas. Storage areas must meet National Electrical Codes for class 1 hazardous areas. Flammable storage areas must be separated from oxygen and other oxidizers by a minimum distance of 20 ft. or by a barrier of non-combustible material at least 5 ft. high having a fire resistance rating of at least _ hour. Post "No Smoking or Open Flames" signs in the storage or use areas. Do not allow storage temperature to exceed 125 °F (52 °C). Storage should be away from heavily traveled areas and emergency exits. Full and empty cylinders should be segregated. Use a first-in first-out inventory system to prevent full containers from being stored for long periods of time.

HANDLING: Do not drag, roll, slide or drop cylinder. Use a suitable hand truck designed for cylinder movement. Never attempt to lift a cylinder by its cap. Secure cylinders at all times while in use. Use a pressure reducing regulator to safely discharge gas from cylinder. Use a check valve to prevent reverse flow

AIR PRODUCTS

MATERIAL SAFETY DATA SHEET

SECTION 1. PRODUCT IDENTIFICATION

PRODUCT NAME: **Methane** **FORMULA:** CH_4
CHEMICAL NAME: Methane, Saturated Alphatic Hydrocarbon, Alkane
SYNONYMS: Methyl Hydride, Marsh Gas, Fire Damp

MANUFACTURER: **Air Products and Chemicals, Inc.**
7201 Hamilton Boulevard
Allentown, PA 18195 - 1501

PRODUCT INFORMATION : (800) 752-1597

MSDS NUMBER: 1070 **REVISION:** 6
REVIEW DATE: July 1999 **REVISION DATE:** July 1999

SECTION 2. COMPOSITION / INFORMATION ON INGREDIENTS

Methane is packaged as pure product (>99%).

CAS NUMBER: 74-82-8

EXPOSURE LIMITS:
OSHA: None established **ACGIH:** Simple Asphyxiant **NIOSH:** None established

SECTION 3. HAZARD IDENTIFICATION

EMERGENCY OVERVIEW

Methane is a flammable, colorless, odorless, compressed gas packaged in cylinders under high pressure. It poses an immediate fire and explosion hazard when mixed with air at concentrations exceeding 5.0%. High concentrations that can cause rapid suffocation are within the flammable range and should not be entered.

EMERGENCY TELEPHONE NUMBERS
800 - 523 - 9374 in Continental U.S. , Canada and Puerto Rico
610 - 481 - 7711 outside U.S.

ACUTE POTENTIAL HEALTH EFFECTS:
ROUTES OF EXPOSURE:
EYE CONTACT: No harmful affect.
INGESTION: Not applicable
INHALATION: Methane is nontoxic. It can, however, reduce the amount of oxygen in the air necessary to support life. Exposure to oxygen-deficient atmospheres (less than 19.5 %) may produce dizziness, nausea, vomiting, loss of consciousness, and death. At very low oxygen concentrations (less than 12 %) unconsciousness and death may occur without warning. It should be noted that before suffocation could occur, the lower flammable limit for Methane in air will be exceeded; causing both an oxygen deficient and an explosive atmosphere.
SKIN CONTACT: No harmful affect.
POTENTIAL HEALTH EFFECTS OF REPEATED EXPOSURE:
ROUTE OF ENTRY: None
SYMPTOMS: None

into cylinder. Never apply flame or localized heat directly to any part of the cylinder. Do not allow any part of the cylinder to exceed 125 °F (52 °C). Use piping and equipment adequately designed to withstand pressures to be encountered. Once cylinder has been connected to properly purged and inerted process, open cylinder valve slowly and carefully. If user experiences any difficulty operating cylinder valve, discontinue use and contact supplier. Never insert an object (e.g., wrench, screwdriver, etc.) into valve cap openings. Doing so may damage valve causing a leak to occur. Use an adjustable strap-wrench to remove over-tight or rusted caps. All piped systems and associated equipment must be grounded. Electrical equipment should be non-sparking or explosion-proof.

SPECIAL PRECAUTIONS: Always store and handle compressed gas cylinders in accordance with Compressed Gas Association, Inc. (telephone 703-412-0900) pamphlet CGA P-1, *Safe Handling of Compressed Gases in Containers*. Local regulations may require specific equipment for storage or use.

SECTION 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

ENGINEERING CONTROLS:

VENTILATION: Provide adequate natural or explosion-proof ventilation to prevent accumulation of gas concentrations above 1.0% Methane (20% of LEL).

RESPIRATORY PROTECTION:

Emergency Use: Do not enter areas where Methane concentration is greater than 1.0% (20% of the LEL). Exposure to concentrations below 1.0% do not require respiratory protection.

EYE PROTECTION: Safety glasses and/or face shield.
SKIN PROTECTION: Leather gloves for handling cylinders. Fire resistant suit and gloves in emergency situations.
OTHER PROTECTIVE EQUIPMENT: Safety shoes are recommended when handling cylinders.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE, ODOR AND STATE: Colorless, odorless, flammable gas.
MOLECULAR WEIGHT: 16.04
BOILING POINT (1 atm): -258.7 °F (-161.5 °C)
SPECIFIC GRAVITY (Air = 1): 0.554
FREEZING POINT / MELTING POINT: -296. 5 °F (-182.5 °C)
VAPOR PRESSURE (At 70 _F (21.1 _C)): Permanent, noncondensable gas.
GAS DENSITY (At 70 _F (21.1 _C) and 1 atm): 0.042 lb/ft^3
SOLUBILITY IN WATER (vol/vol): 3.3 ml gas / 100 ml

SECTION 10. STABILITY AND REACTIVITY

CHEMICAL STABILITY: Stable
CONDITIONS TO AVOID: Cylinders should not be exposed to temperatures in excess of 125 °F (52 °C).
INCOMPATIBILITY (Materials to Avoid): Oxygen, Halogens and Oxidizers
REACTIVITY:

A) HAZARDOUS DECOMPOSITION PRODUCTS: None
B) HAZARDOUS POLYMERIZATION: Will not occur

SECTION 11. TOXICOLOGICAL INFORMATION

LC_{50} (Inhalation): Not applicable. Simple asphyxiant.
LD_{50} (Oral): Not applicable
LD_{50} (Dermal): Not applicable

SKIN CORROSIVITY: Methane is not corrosive to the skin.
ADDITIONAL NOTES: None

SECTION 12. ECOLOGICAL INFORMATION

AQUATIC TOXICITY: Not determined
MOBILITY: Not determined
PERSISTENCE AND BIODEGRADABILITY: Not determined
POTENTIAL TO BIOACCUMULATE: Not determined
REMARKS: This product does not contain any Class I or Class II ozone depleting chemicals.

SECTION 13. DISPOSAL CONSIDERATIONS

UNUSED PRODUCT / EMPTY CONTAINER: Return container and unused product to supplier. Do not attempt to dispose of residual or unused quantities.

DISPOSAL INFORMATION: Residual product in the system may be burned if a suitable burning unit (flair incinerator) is available on site. This shall be done in accordance with federal, state, and local regulations. Wastes containing this material may be classified by EPA as hazardous waste by characteristic (i.e., Ignitability, Corrosivity, Toxicity, Reactivity). Waste streams must be characterized by the user to meet federal, state, and local requirements.

SECTION 14. TRANSPORT INFORMATION

DOT SHIPPING NAME: Methane, compressed
HAZARD CLASS: 2.1
IDENTIFICATION NUMBER: UN1971
SHIPPING LABEL(s): Flammable gas
PLACARD (When required): Flammable gas

SPECIAL SHIPPING INFORMATION: Cylinders should be transported in a secure upright position in a well-ventilated truck. Never transport in passenger compartment of a vehicle. Ensure cylinder valve is properly closed, valve outlet cap has been reinstalled, and valve protection cap is secured before shipping cylinder.

CAUTION: Compressed gas cylinders shall not be refilled except by qualified producers of compressed gases. Shipment of a compressed gas cylinder which has not been filled by the owner or with the owner's written consent is a violation of Federal law (49 CFR 173.301).

NORTH AMERICAN EMERGENCY RESPONSE GUIDEBOOK NUMBER (NAERG #): 115

SECTION 15. REGULATORY INFORMATION

U.S. FEDERAL REGULATIONS:

EPA - ENVIRONMENTAL PROTECTION AGENCY

CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (40 CFR Parts 117 and 302)
Reportable Quantity (RQ): None

SARA TITLE III: Superfund Amendment and Reauthorization Act

SECTIONS 302/304: Emergency Planning and Notification (40 CFR Part 355)
Extremely Hazardous Substances: Methane is not listed.
Threshold Planning Quantity (TPQ): None
Reportable Quantity (RQ): None

SECTIONS 311/312: Hazardous Chemical Reporting (40 CFR Part 370)

IMMEDIATE HEALTH:	Yes	PRESSURE:	Yes
DELAYED HEALTH:	No	REACTIVITY:	No
		FIRE:	Yes

SECTION 313: Toxic Chemical Release Reporting (40 CFR Part 372)
Methane does not require reporting under Section 313.

AIR PRODUCTS

MATERIAL SAFETY DATA SHEET

SECTION 1. PRODUCT IDENTIFICATION

PRODUCT NAME: **Nitrogen, compressed**
CHEMICAL NAME: Nitrogen
FORMULA: N_2
SYNONYMS: Nitrogen gas, Gaseous Nitrogen, GAN

MANUFACTURER: **Air Products and Chemicals, Inc.**
7201 Hamilton Boulevard
Allentown, PA 18195 - 1501
PRODUCT INFORMATION: 1-800-752-1597
MSDS NUMBER: 1011 **REVISION:** 5
REVISION DATE: March 1994 **REVIEW DATE:**
August 1997

SECTION 2. COMPOSITION/INFORMATION ON INGREDIENTS

Nitrogen is sold as pure product > 99%.
CAS NUMBER: 7727-37-9
EXPOSURE LIMITS:
OSHA: Not established **ACGIH:** Simple asphyxiant **NIOSH:** Not established

SECTION 3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

Nitrogen is a nontoxic, odorless, colorless, nonflammable compressed gas stored in cylinders at high pressure. It can cause rapid suffocation when concentrations are sufficient to reduce oxygen levels below 19.5%. Self Contained Breathing Apparatus (SCBA) may be required.

EMERGENCY TELEPHONE NUMBERS
800-523-9374 Continental U.S. , Canada and Puerto Rico
610-481-7711 other locations

POTENTIAL HEALTH EFFECTS INFORMATION:

INHALATION: Simple asphyxiant. Nitrogen is nontoxic, but may cause suffocation by displacing the oxygen in air. Lack of sufficient oxygen can cause serious injury or death.

EYE CONTACT: No adverse effect.

SKIN CONTACT: No adverse effect.

EXPOSURE INFORMATION:

ROUTE OF ENTRY: Inhalation

TARGET ORGANS: None

CLEAN AIR ACT:

SECTION 112 (r): Risk Management Programs for Chemical Accidental Release (40 CFR PART 68)
Methane is listed as a regulated substance.
Threshold Planning Quantity (TPQ): 10,000 lbs

TSCA: Toxic Substance Control Act
Methane is listed on the TSCA inventory.

OSHA - OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION:

29 CFR Part 1910.119: Process Safety Management of Highly Hazardous Chemicals
Methane is not listed in Appendix A as a highly hazardous chemical. However, any process that involves a flammable gas on site in one location, in quantities of 10,000 pounds
(4,553 kg) or greater is covered under this regulation unless it is used as fuel.

STATE REGULATIONS:

CALIFORNIA:
Proposition 65: This product is not a listed substance which the State of California requires warning under this statute.

SECTION 16. OTHER INFORMATION

NFPA RATINGS:		HMIS RATINGS:	
HEALTH:	= 1	HEALTH:	= 0
FLAMMABILITY:	= 4	FLAMMABILITY:	= 4
REACTIVITY:	= 0	REACTIVITY:	= 0
SPECIAL:	= SA*		

*SA denotes "Simple Asphyxiant" per Compressed Gas Association recommendation.

damage valve causing a leak to occur. Use a special cap wrench or adjustable strap-wrench to remove over-tight or rusted caps.

Nitrogen is compatible with all common materials of construction. Pressure requirements should be considered when selecting materials and designing systems.

SPECIAL REQUIREMENTS: Always store and handle compressed gases in accordance with Compressed Gas Association, Inc. (ph. 703-412-0900) pamphlet CGA P-1, *Safe Handling of Compressed Gases in Containers*. Local regulations may require specific equipment for storage or use.

CAUTION: Users of nitrogen must be aware of the hazards caused by the accumulation of high concentrations, especially in confined spaces. Compliance with OSHA regulations, especially 29 CFR 1910.146 (confined space entry), is essential

SECTION 8. PERSONAL PROTECTION / EXPOSURE CONTROL

ENGINEERING CONTROLS: Provide good ventilation and/or local exhaust to prevent accumulation of high concentrations of gas. Oxygen levels in work area should be monitored to ensure they do not fall below 19.5%.

RESPIRATORY PROTECTION:

GENERAL USE: None required.

EMERGENCY: Use SCBA or positive pressure air line with mask and escape pack in areas where oxygen concentration is less than 19.5%. Air purifying respirators will not provide protection.

OTHER PROTECTIVE EQUIPMENT: Safety glasses. Safety shoes and leather work gloves are recommended when handling cylinders.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE: Colorless gas

ODOR: Odorless

MOLECULAR WEIGHT: 28.01

BOILING POINT (1 Atm): -320.4 °F (-195.8 °C)

SPECIFIC GRAVITY (Air =1): 0.967

SPECIFIC VOLUME (at 70 °F (21.1 °C) and 1 atm): 13.81 ft^3/lb (0.867m^3/kg)

FREEZING POINT/MELTING POINT: -345.8 °F (-209.9 °C)

VAPOR PRESSURE: Not applicable at 70 °F

GAS DENSITY (at 70 °F (21.1 °C) and 1 atm): 0.072 lb/ft^3 (1.153 kg/m^3)

SOLUBILITY IN WATER (Vol./Vol. at 32°F (0°C)): 0.023

SECTION 10. STABILITY AND REACTIVITY

CHEMICAL STABILITY: Stable

CONDITIONS TO AVOID: None

INCOMPATIBILITY: None

HAZARDOUS DECOMPOSITION PRODUCTS: None

HAZARDOUS POLYMERIZATION: Will not occur.

SECTION 11. TOXICOLOGICAL INFORMATION

Nitrogen is a simple asphyxiant.

EFFECT: Asphyxiation (suffocation)

SYMPTOMS: Exposure to an oxygen deficient atmosphere (<19.5%) may cause dizziness, drowsiness, nausea, vomiting, excess salivation, diminished mental alertness, loss of consciousness and death. Exposure to atmospheres containing 8-10% or less oxygen will bring about unconsciousness without warning and so quickly that the individuals cannot help themselves.

MEDICAL CONDITIONS AGGRAVATED BY OVEREXPOSURE: None

CARCINOGENIC POTENTIAL: Nitrogen is not listed as a carcinogen or potential carcinogen by NTP, IARC, or OSHA .

SECTION 4. FIRST AID

INHALATION: Persons suffering from lack of oxygen should be moved to fresh air. If victim is not breathing, administer artificial respiration. If breathing is difficult, administer oxygen. Obtain prompt medical attention.

EYE CONTACT: Not applicable.

SKIN CONTACT: Not applicable.

SECTION 5. FIRE AND EXPLOSION

FLASH POINT:	AUTOIGNITION:	FLAMMABLE LIMITS:
Not applicable	Nonflammable	Nonflammable

EXTINGUISHING MEDIA: Nitrogen is nonflammable and does not support combustion. Use extinguishing media appropriate for the surrounding fire.

HAZARDOUS COMBUSTION PRODUCTS: None

SPECIAL FIRE FIGHTING INSTRUCTIONS: Nitrogen is a simple asphyxiant. If possible, remove nitrogen cylinders from fire area or cool with water. SCBA may be required by rescue workers.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Upon exposure to intense heat or flame cylinder may vent rapidly and/or rupture violently. Most cylinders are designed to vent contents when exposed to elevated temperatures. Pressure in a container can build up due to heat and it may rupture if pressure relief devices should fail to function.

SECTION 6. ACCIDENTAL RELEASE MEASURES

Evacuate all personnel from affected area. Increase ventilation to release area and monitor oxygen level. Use appropriate protective equipment (SCBA). If leak is from container or its valve, call the Air Products emergency telephone number. If leak is in user's system close cylinder valve and vent pressure before attempting repairs.

SECTION 7. HANDLING AND STORAGE

STORAGE: Cylinders should be stored upright in a well-ventilated, secure area, protected from the weather. Storage area temperatures should not exceed 125 °F (52 °C) and area should be free of combustible materials. Storage should be away from heavily traveled areas and emergency exits. Avoid areas where salt or other corrosive materials are present. Valve protection caps and valve outlet seals should remain on cylinders not connected for use. Separate full from empty cylinders. Avoid excessive inventory and storage time. Use a first-in first-out system. Keep good inventory records.

HANDLING: Do not drag, roll, or slide cylinder. Use a suitable handtruck designed for cylinder movement. Never attempt to lift a cylinder by its cap. Secure cylinders at all times while in use. Use a pressure reducing regulator or separate control valve to safely discharge gas from cylinder. Use a check valve to prevent reverse flow into cylinder. Do not overheat cylinder to increase pressure or discharge rate. If user experiences any difficulty operating cylinder valve, discontinue use and contact supplier. Never insert an object (e.g., wrench, screwdriver, pry bar, etc.) into valve cap openings. Doing so may

40 CFR Part 68 - Risk Management for Chemical Accident Release Prevention: Requires the development and implementation of risk management programs at facilities that manufacture, use, store, or otherwise handle regulated substances in quantities that exceed specified thresholds.

Nitrogen is not listed as a regulated substance.

TSCA - TOXIC SUBSTANCES CONTROL ACT: Nitrogen is listed on the TSCA inventory.

OSHA - OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION:

29 CFR 1910.119 - Process Safety Management of Highly Hazardous Chemicals: Requires facilities to develop a process safety management program based on Threshold Quantities (TQ) of highly hazardous chemicals.

Nitrogen is not listed in Appendix A as a highly hazardous chemical.

STATE REGULATIONS

CALIFORNIA:

Proposition 65: This product does NOT contain any listed substances which the State of California requires warning under this statute.

SCAQMD Rule: VOC = Not applicable

SECTION 16. OTHER INFORMATION

NFPA RATINGS:		HMIS RATINGS:	
HEALTH:	0	HEALTH:	0
FLAMMABILITY:	0	FLAMMABILITY:	0
REACTIVITY:	0	REACTIVITY:	0
SPECIAL:	SA*		

*Compressed Gas Association recommendation to designate simple asphyxiant.

*** Documents with Review Dates August 1997 and Revision Date March 1994 are identical in content and either may be used.*

SECTION 12. ECOLOGICAL INFORMATION

The atmosphere contains approximately 78% nitrogen. No adverse ecological effects are expected. Nitrogen does not contain any Class I or Class II ozone depleting chemicals. Nitrogen is not listed as a marine pollutant by DOT (49 CFR 171).

SECTION 13. DISPOSAL

UNUSED PRODUCT / EMPTY CONTAINER: Return cylinder and unused product to supplier. Do not attempt to dispose of residual or unused quantities.

DISPOSAL: For emergency disposal, secure the cylinder and slowly discharge gas to the atmosphere in a well ventilated area or outdoors.

SECTION 14. TRANSPORT INFORMATION

DOT HAZARD CLASS: 2.2 **DOT SHIPPING LABEL:** Nonflammable Gas

DOT SHIPPING NAME: Nitrogen, Compressed **IDENTIFICATION NUMBER:** UN1066

REPORTABLE QUANTITY (RQ): None

SPECIAL SHIPPING INFORMATION: Cylinders should be transported in a secure upright position in a well ventilated truck. Never transport in passenger compartment of a vehicle.

Compressed gas cylinders shall not be refilled except by qualified producers of compressed gases. Shipment of a compressed gas cylinder which has not been filled by the owner or with the owner's written consent is a violation of federal law.

SECTION 15. REGULATORY INFORMATION

U.S. FEDERAL REGULATIONS:

ENVIRONMENTAL PROTECTION AGENCY (EPA):

CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act of 1980 requires notification to the National Response Center of a release of quantities of hazardous substances equal to or greater than their reportable quantities (RQ's) in 40 CFR 302.4.

CERCLA Reportable Quantity: None.

SARA TITLE III: Superfund Amendment and Reauthorization Act of 1986

SECTION 302/304: Requires emergency planning on threshold planning quantities (TPQ) and release reporting based on reportable quantities (RQ) of EPA's extremely hazardous substances (40 CFR 355).

Nitrogen is not listed as an extremely hazardous substance.

Threshold Planning Quantity (TPQ): None

SECTIONS 311/312: Require submission of material safety data sheets (MSDSs) and chemical inventory reporting with identification of EPA defined hazard classes. The hazard classes for this product are:

IMMEDIATE HEALTH: No	PRESSURE: Yes
DELAYED HEALTH: No	REACTIVITY: No
	FIRE: No

SECTION 313: Requires submission of annual reports of release of toxic chemicals that appear in 40 CFR 372.

Nitrogen does not require reporting under Section 313.

EXPOSURE INFORMATION:

ROUTE OF ENTRY: Inhalation

TARGET ORGANS: Eyes, central nervous system

MEDICAL CONDITIONS AGGRAVATED BY OVEREXPOSURE: Patients with chronic obstructive pulmonary disease retain carbon dioxide abnormally. If oxygen is administered to them, raising the oxygen concentration in the blood depresses their breathing and raises their retained carbon dioxide to a dangerous level.

CARCINOGENIC POTENTIAL: Oxygen is not listed as a carcinogen or potential carcinogen by NTP, IARC, or OSHA Subpart Z.

SECTION 4. FIRST AID

INHALATION: Move victim to fresh air or if in elevated pressures reduce oxygen pressures to one atmosphere. Call a physician. The physician should be advised that the victim has been exposed to a high concentration of oxygen. No treatment is required in the absence of symptoms or high pressure exposure.

EYE / SKIN CONTACT: Not applicable

NOTES TO PHYSICIAN: Animal studies suggest that the administration of certain drugs, including phenothiazine drugs and chloroquine, increase the susceptibility to toxicity from oxygen at high pressures. Animal studies also indicate that vitamin "E" deficiency may increase susceptibility to oxygen toxicity.

Airway obstruction during high oxygen tension may cause alveolar collapse following absorption of the oxygen. Similarly, occlusion of the Eustachian tubes may cause retraction of the eardrum and obstruction of the paranasal sinuses may produce "vacuum-type" headache.

All individuals exposed for long periods to oxygen at high pressure and who exhibit overt oxygen toxicity should have ophthalmologic examinations.

SECTION 5. FIRE AND EXPLOSION

FLASH POINT:	AUTOIGNITION:	FLAMMABLE LIMITS:
Not applicable	Nonflammable	Nonflammable

EXTINGUISHING MEDIA: Oxygen is nonflammable but will support combustion. Use extinguishing media appropriate for surrounding fire.

HAZARDOUS COMBUSTION PRODUCTS: None

SPECIAL FIRE FIGHTING INSTRUCTIONS: Evacuate all personnel from the danger area. If possible, shut off flow of oxygen which is supporting the fire. Immediately cool containers with water spray from maximum distance. When cool move cylinders from fire area, if possible without risk. Self contained breathing apparatus may be required for rescue workers.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Oxygen vigorously accelerates combustion. Some materials which are noncombustible in air will burn in the presence of an oxygen enriched atmosphere (greater than 23%). Fire resistant clothing may burn and offer no protection in oxygen rich atmospheres. Oxygen may form explosive compounds when exposed to combustible materials or oil, grease, and other hydrocarbon materials. Pressure in a container can build up due to heat and it may rupture if pressure relief devices should fail to function. Upon exposure to intense heat or flame cylinder will vent rapidly and/or rupture violently. Most cylinders are designed to vent contents when exposed to elevated temperatures. Pressure in a container can build up due to heat and it may rupture if pressure relief devices should fail to function.

AIR PRODUCTS

MATERIAL SAFETY DATA SHEET

SECTION 1. PRODUCT IDENTIFICATION

PRODUCT NAME: **Oxygen, Compressed**

CHEMICAL NAME: **Oxygen** **FORMULA:** O_2

SYNONYMS: Oxygen gas, Gaseous Oxygen, GOX

MANUFACTURER: **Air Products and Chemicals, Inc.**
7201 Hamilton Boulevard
Allentown, PA 18195 - 1501

PRODUCT INFORMATION: 1-800-752-1597

MSDS NUMBER: 1012 **REVISION:** 5

REVISION DATE: January 1995 **REVIEW DATE:** August 1997**

SECTION 2. COMPOSITION / INFORMATION ON INGREDIENTS

Oxygen is sold as pure product > 99%.

CAS NUMBER: 7782-44-7

EXPOSURE LIMITS:

OSHA: Not established **ACGIH:** Not established **NIOSH:** Not established

SECTION 3. HAZARD IDENTIFICATION

EMERGENCY OVERVIEW

Oxygen is an odorless, colorless, nonflammable gas stored in cylinders at high pressure. It is an oxidizing gas and vigorously accelerates combustion. Keep away from oils or grease. Rescue personnel should be aware of the extreme fire hazards associated with oxygen-enriched (greater than 23%) atmospheres, and that self contained breathing apparatus (SCBA) may be required.

EMERGENCY TELEPHONE NUMBERS

(800) 523-9374 Continental U.S., Canada and Puerto Rico

(610) 481-7711 other locations

POTENTIAL HEALTH EFFECTS INFORMATION:

INHALATION: Breathing 80% or more oxygen at atmospheric pressure for more than a few hours may cause nasal stuffiness, cough, sore throat, chest pain and breathing difficulty. Breathing oxygen at higher pressure increases the likelihood of adverse effects within a shorter time period. Breathing pure oxygen under pressure may cause lung damage and also central nervous system effects resulting in dizziness, poor coordination, tingling sensation, visual and hearing disturbances, muscular twitching, unconsciousness and convulsions. Breathing oxygen under pressure may cause prolongation of adaptation to darkness and reduced peripheral vision.

EYE / SKIN CONTACT: No adverse effect.

OTHER PROTECTIVE EQUIPMENT: Safety shoes and work gloves are recommended when handling cylinders. Clothing exposed to high concentrations may retain oxygen 30 minutes or longer and become a potential fire hazard. Stay away from ignition sources.

SECTION 6. ACCIDENTAL RELEASE MEASURES

Evacuate all personnel from affected area. Shut off source of oxygen if possible. Increase ventilation to release area. Personnel who have been exposed to high concentrations of oxygen should stay in a well-ventilated or open area for 30 minutes before going into a confined space or near an ignition source.
If leak is from container or its valve, call the Air Products emergency telephone number. If leak is in user's system close cylinder valve and vent pressure before attempting repairs.

SECTION 7. STORAGE AND HANDLING

STORAGE: Cylinders should be stored upright in a well-ventilated, secure area, protected from the weather. Storage area temperatures should not exceed 125 °F (52 °C) and area should be free of combustible materials. Storage should be away from heavily traveled areas and emergency exits. Avoid areas where salt or other corrosive materials are present. Cylinders should be separated from flammables by a minimum distance of 20 ft. or by a barricade of non-combustible material at least five ft. high having a fire resistance rating of at least 1/2 hour. Valve protection caps and valve outlet seals should remain on cylinders not connected for use. Separate full from empty cylinders. Avoid excessive inventory and storage time. Use a first-in first-out system. Keep good inventory records.

HANDLING: Do not drag, roll, or slide cylinder. Use a suitable handtruck designed for cylinder movement. Never attempt to lift a cylinder by its cap. Secure cylinders at all times while in use. Use a pressure reducing regulator or separate control valve to safely discharge gas from cylinder. Use a check valve to prevent reverse flow into cylinder. Do not overheat cylinder to increase pressure or discharge rate. Always open cylinder valve slowly. Do not use rapid opening valves (i.e., ball valves). If user experiences any difficulty operating cylinder valve, discontinue use and contact supplier. Never insert an object (e.g., wrench, screwdriver, pry bar, etc.) into valve cap openings. Doing so may damage valve causing a leak to occur. Use an adjustable strap-wrench to remove over-tight or rusted caps.

All gauges, valves, regulators, piping and equipment to be used in oxygen service must be cleaned for oxygen service in accordance with Compressed Gas Association pamphlet G-4.1.

Carbon steel, stainless steel, copper, brass, nickel and their alloys are materials of construction that can be used in oxygen service. Use piping and equipment adequately designed to withstand pressures to be encountered. Oxygen is not to be used as a substitute for compressed air. Never use an oxygen jet for cleaning purposes of any sort, especially clothing, as it increases the likelihood of an engulfing fire. Use a check valve or other protective apparatus in any line or piping from the cylinder to prevent reverse flow.

When used in welding and cutting read and understand the manufacturer's instructions and the precautionary label on the products. Never strike an arc on a compressed gas cylinder or make a cylinder a part of an electrical circuit.

SPECIAL REQUIREMENTS: Always store and handle compressed gases in accordance with Compressed Gas Association, Inc. (ph. 703-412-0900) pamphlet CGA P-1, *Safe Handling of Compressed Gases in Containers*. Local regulations may require specific equipment for storage or use.

CAUTION: Compressed gas cylinders shall not be refilled except by qualified producers of compressed gases. Shipment of a compressed gas cylinder which has not been filled by the owner or with the owner's written consent is a violation of federal law.

SECTION 8. PERSONAL PROTECTION / EXPOSURE CONTROL

ENGINEERING CONTROLS: Provide ventilation and/or local exhaust to prevent accumulation of high concentrations of gas (greater than 23%).

RESPIRATORY PROTECTION:

GENERAL USE: None required

EMERGENCY: Use SCBA do to possibility of fire when concentrations exceed 23%.

SPECIAL SHIPPING INFORMATION: Cylinders should be transported in a secure upright position in a well ventilated truck. Never transport in passenger compartment of a vehicle. An oxygen label may be used for domestic shipment in the United States and Canada in place of the Non-flammable and Oxidizer labels (49CFR Part 172).

SECTION 15. REGULATORY INFORMATION

U.S. FEDERAL REGULATIONS:

EPA - ENVIRONMENTAL PROTECTION AGENCY:

CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act of 1980 requires notification to the National Response Center of releases of quantities of hazardous substances equal to or greater than the reportable quantities (RQ) in 40 CFR 302.4.

CERCLA Reportable Quantity: None

SARA TITLE III: Superfund Amendments and Reauthorization Act of 1986

SECTION 302: Requires emergency planning based on threshold planning quantities (TPQ) and release reporting based on reportable quantities (RQ) of EPA's extremely hazardous substances (40 CFR 355).

Oxygen is not listed as an Extremely Hazardous Substance.

SECTIONS 311/312: Require submission of material safety data sheets (MSDSs) and chemical inventory reporting with identification of EPA defined hazard classes. The hazard classes for this product are:

IMMEDIATE:	No	PRESSURE:	Yes
DELAYED:	No	REACTIVITY:	No
		FIRE:	Yes

SECTION 313: Requires submission of annual reports of releases of toxic chemicals that appear in

40 CFR 372.

Oxygen is not listed as a toxic chemical.

40 CFR PART 68: Risk Management for Chemical Accident Release Prevention. Requires the development and implementation of risk management programs at facilities that manufacture, use, store, or otherwise handle regulated substances in quantities that exceed specified thresholds.

Oxygen is not listed as a regulated substance.

TOXIC SUBSTANCE CONTROL ACT (TSCA): Oxygen is listed on the TSCA inventory.

OSHA - OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

29 CFR 1910.119: Process Safety Management of Highly Hazardous Chemicals. Requires facilities to develop a process safety management program based on Threshold Quantities (TQ) of highly hazardous chemicals.

Oxygen is not listed as a Highly Hazardous Chemical.

STATE REGULATIONS

CALIFORNIA:

Proposition 65:This product does NOT contain any listed substances for which the State of California requires warning under this statute.

SCAQMD Rule: VOC = Not applicable

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE: Colorless gas
ODOR: Odorless
MOLECULAR WEIGHT: 32.0
BOILING POINT (1 atm): -297.3 °F (-183.0 °C)
SPECIFIC GRAVITY (Air =1): 1.10
SPECIFIC VOLUME (at 70 °F 21.1 °C) and 1 atm): 12.08 ft^3/lb (0.754 m^3/kg)
FREEZING / MELTING POINT: -361.9 °F (-218.8 °C)
VAPOR PRESSURE: Not applicable at 70°F
GAS DENSITY (At 70°F (21.1°C) and 1 Atm): 0.083 lb /ft^3 (1.326 kg/m^3)
SOLUBILITY IN WATER (Vol./Vol. at 32°F (0°C)): 0.049

SECTION 10. REACTIVITY / STABILITY

CHEMICAL STABILITY: Stable
CONDITIONS TO AVOID: None
INCOMPATIBILITY: Oils, grease, hydrocarbons and flammable materials.
HAZARDOUS DECOMPOSITION PRODUCTS: None
HAZARDOUS POLYMERIZATION: Will not occur

SECTION 11. TOXICOLOGICAL INFORMATION

At atmospheric concentration and pressure, oxygen poses no toxicity hazards.

Premature infants exposed to high oxygen concentrations may suffer delayed retinal damage which can progress to retinal detachment and blindness. Retinal damage may also occur in adults exposed to 100% oxygen for extended periods (24 to 48 hr).

At two or more atmospheres central nervous system (CNS) toxicity occurs. Symptoms include nausea, vomiting, dizziness or vertigo, muscle twitching, vision changes, and loss of consciousness and generalized seizures. At three atmospheres, CNS toxicity occurs in less than two hours, and at six atmospheres in only a few minutes.

SECTION 12. ECOLOGICAL INFORMATION

The atmosphere contains 21% oxygen. No adverse ecological effects are expected. Oxygen does not contain any Class I or Class II ozone depleting chemicals. Oxygen is not listed as a marine pollutant by DOT (49 CFR 171).

SECTION 13. DISPOSAL

UNUSED PRODUCT / EMPTY CONTAINER: Return container and unused product to supplier. Do not attempt to dispose of residual or unused quantities.

DISPOSAL: For emergency disposal, secure cylinder and slowly discharge gas to the atmosphere in a well ventilated area or outdoors.

SECTION 14. TRANSPORTATION

DOT HAZARD CLASS: 2.2 (Nonflammable Gas)
DOT SHIPPING LABEL: Nonflammable Gas, Oxidizer
DOT SHIPPING NAME: Oxygen, compressed
IDENTIFICATION NUMBER: UN 1072
REPORTABLE QUANTITY (RQ): None
PLACARD: Nonflammable Gas or Oxygen

Ferrellgas Material Safety Data Sheet - Propane

Ferrellgas One Liberty Plaza Liberty, MO 64068

Section 1: Emergency Information

24 Hour Emergency Number

Call 1-800-424-9300 (Chemtrec) in case of emergencies involving propane.

Warning!

Extremely flammable compressed gas.

- Asphyxiant in high concentrations.
- Skin contact with liquid causes burns similar to frostbite.
- Ethyl mercaptan used as a warning agent may not be entirely effective in all situations. Read the warnings in section 9.

NFPA hazard rating

Hazard ratings are in the following table

Health hazard = 1
Fire hazard = 4
Reactivity = 0

Where:

0 = Least	3 = High
1 = Slight	4 = Extreme
2 = Moderate	

General MSDS assistance

Call 816-792-1600 and ask to speak with the Safety Department for general assistance with questions about this MSDS.

Section 2: Hazardous Components/Identity Information

Product

Propane (odorized)

Chemical name

Propane

Chemical family

Liquefied Petroleum Gas (Paraffinic Hydrocarbons)

Hazardous components

Propane may contain various percentages of these hazardous components, depending on the source of supply.

Component	CAS Number	Percentage
Propane	74-98-6	85 - 100
Propylene	115-07-1	0 - 15
Butane and heavier	106-97-8	0 - 2.5
Ethane	74-84-0	0 - 5
Ethyl Mercaptan (Odorant)	75-08-1	<0.0025

SECTION 16. SUPPLEMENTAL INFORMATION

HAZARD RATINGS:

NFPA RATINGS:		HMIS RATINGS:	
HEALTH:	0	HEALTH:	0
FLAMMABILITY:	0	FLAMMABILITY:	0
REACTIVITY:	0	REACTIVITY:	0
SPECIAL:	OX (oxidizer)		

**Documents with Revision Date January 1995 and Review Date August 1997 are identical in content and either may be used.

Section 3: Health Information

Purpose — The health effects are consistent with requirements of the OSHA Hazard Communication Standard (29 CFR 1910.1200).

Eye contact — Direct contact with liquid propane can result in eye burns.

Skin contact — Direct contact with liquid propane can result in skin burns (frostbite).

Inhalation — This product is classified as a simple asphyxiant.
High vapor concentrations may produce a reversible central nervous system depression (anesthesia).
Higher concentrations may produce asphyxiation.

Ingestion — Ingestion is not likely.

Signs and symptoms — Eye or skin burns (frostbite) as noted previously.
Early to moderate central nervous system depression may be evidenced by giddiness, headache, dizziness and nausea. In extreme cases, unconsciousness may occur.
Asphyxiation may be noted by a sudden loss of consciousness. Death may quickly follow.

Aggravated medical conditions — Caution is recommended for personnel with pre-existing central nervous system or chronic respiratory diseases.

Acute toxicity data — Acute toxicity data is not applicable to this product.

Carcinogenicity — This product is not classified as a carcinogen.

Occupational exposure limits — Use this table to determine the allowable exposure limits for personnel.

OSHA		ACGIH	
PEL/TWA	PEL/Ceiling	TLV/TWA	TLV/STEL
Propane: 1,000 PPM Butane: 800 PPM	Not established	Butane: 800 PPM	Not established

Cardiac effects — While there is no evidence that exposure to industrially acceptable levels of hydrocarbons have produced cardiac effects in humans, animal studies have shown that inhalation of high vapor levels of the components of this product have produced cardiac sensitization. Such sensitization may cause fatal changes in heart rhythms. This latter effect was shown to be enhanced by hypoxia or the injection of adrenaline-like agents.

Effects of propylene — Laboratory animals exposed to high levels of propylene for prolonged periods of time showed evidence of effects in the liver, kidneys, and nasal cavity.

Section 4: Emergency and First Aid Procedures

Purpose — Follow these procedures in case of personal injuries resulting from use of this product.

Eye contact with liquid — Flush eyes with water. Get medical attention.

Skin contact with liquid — Flush with water. If frostbite or burn occurs, get medical attention.

Inhalation — Remove victim to fresh air and provide oxygen if breathing is difficult.
Seek immediate medical attention if victim is not breathing. Give artificial respiration.

Ingestion — Not applicable to this product.

Section 5: Physical Data

Physical properties — Refer to this table for the physical properties of this product.

Property	Value
Appearance and odor	Colorless gas, liquid under pressure. Mercaptan "rotten cabbage" odor
Boiling point	-44 degrees F.
Evaporation rate (Butyl Acetate = 1)	<1 (diffuses readily)
Flash point	-156 degrees F.
Liquid to vapor expansion ratio	1:270
Molecular weight	44.096
Solubility in water	Slight
Specific gravity (liquid)	0.500 - 0.510 (Water = 1)
Specific gravity (vapor)	1.52 (Air = 1)
Vapor pressure (maximum)	208 PSIG @ 100 degrees F.

Section 6: Fire and Explosion Hazards

Flammability limits — Flammability limits by volume in air.
- Lower 2.15 percent
- Upper 9.6 percent

Ignition temperature — Auto Ignition temperature is 940 degrees, F.

Extinguishing media — Allow product to burn if source cannot be shut off safely.
- Class B-C or A-B-C dry chemical or halon extinguishers can be used on small fires.
- Apply water from a safe distance to cool containers, surrounding equipment, and structures.

Continued on next page

Section 6: Fire and Explosion Hazards, Continued

Special fire fighting procedures and precautions	Extremely flammable. Containers may explode if not sufficiently cooled with water spray. Evacuate surrounding area of unprotected personnel and isolate. Do not enter confined fire space without full bunker gear (helmet with face shield, bunker coats, gloves, and rubber boots) and a positive pressure NIOSH approved self-contained breathing apparatus.

Section 7: Reactivity

Stability and hazardous polymerization	This product is stable. Hazardous polymerization will not occur.
Conditions and materials to avoid	Avoid heat, sparks, flame and contact with strong oxidizing agents. Avoid buildups of static electricity. • Prevent vapor accumulation.
Hazardous decomposition products	Carbon monoxide and unidentified organic products may be formed during combustion.

Section 8: Employee Protection

Respiratory protection	Use a NIOSH approved respirator as required when airborn exposure limits are exceeded. • In accord with 29 CFR 1910.134, use either an atmosphere supplying respirator or an air purifying respirator for organic vapors.
Protective clothing	Avoid liquid contact with eyes or skin. • Wear safety glasses or goggles as appropriate. • Wear protective clothing as appropriate.
Additional protective measures	Use explosion-proof ventilation as required to control vapor concentrations.

Section 9: Precautions For Safe Handling and Use

Release, spill or leak procedures	**Warning!** Extremely flammable. • Eliminate sources of ignition. • Isolate hazard area and deny entry to unnecessary or unprotected personnel. • Stay upwind and keep out of low areas. • Notify local fire department. • Disperse vapor clouds with water spray. • Shut off source of leak only if it can be done safely.

Continued on next page

Section 9: Precautions For Safe Handling and Use, Continued

Training	Train all personnel involved in handling propane in proper handling and operating procedures. • Document all training.
Handling and storing	Handle and store propane in accordance with NFPA 58 and local fire codes. • Keep containers away from heat sources or temperatures exceeding 130 degrees F. • Do not drop or roll any container. • Store and transport containers with relief valves in vapor space. • Keep all container valves closed when not in use. • Keep protective caps (if applicable) on containers when not in use.
DOT cylinders	Take these precautions when using DOT cylinders. • Periodically inspect and requalify DOT cylinders in accordance with DOT and NFPA 58 codes and Compressed Gas Association Pamphlets C-6 and C-6a. • Store and use cylinders with valves off and the relief valves in the container vapor space. • Shut all valves and follow recommended procedures before exchanging cylinders.
Special precautions	Containers, even those that have been emptied, can contain explosive vapors. • Do not cut, drill, grind, weld or perform similar operations on or near containers.
Propane odorization	**Warning!** Any smell of odorant, even a faint one, may indicate a dangerous situation. Ethyl mercaptan is the preferred warning agent for propane. Although ethyl mercaptan has excellent warning properties, "It is recognized that no odorant will be completely effective as a warning agent in every circumstance" (NFPA 58 A-1-4.1, 1992 edition). Instances in which odorants may lose their effectiveness include, but are not limited to: • Odor may fade due to chemical oxidation in improperly prepared new tanks and cylinders or from rust, air, and water in used containers that have been allowed to stand open to the atmosphere. • Odor may be absorbed and adsorbed by the walls of containers and distribution systems. • Odor in the gas escaping from underground leaks may be absorbed by certain types of soils. • Effectiveness of the odorant may be reduced by cold temperatures. • Other odors, such as from cooking or from a musty basement, may mask or cover up the mercaptan odor in propane. • Exposure to the mercaptan odor of propane for extended periods of time may affect a person's ability to detect the odorant. • Physical disabilities or the use of alcohol, tobacco, or drugs may decrease a person's ability to detect the odorant.

Section 10: Transportation Requirements

DOT shipping name	Liquefied Petroleum Gas
DOT classification	Division 2.1 (Flammable Gas)
Other transportation requirements	UN 1075, Hazardous Materials Guide Number 115. North American Industrial Classification System (NAICS) Number 454312

MATHESON TRI•GAS
ask. . .The Gas Professionals™

MATERIAL SAFETY DATA SHEET

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

MATHESON TRI-GAS, INC.
150 Allen Road Suite 302
Basking Ridge, New Jersey 07920
Information: 1-800-416-2505

Emergency Contact:
CHEMTREC 1-800-424-9300
Calls Originating Outside the US:
703-527-3887 (Collect Calls Accepted)

SUBSTANCE: PROPYLENE

TRADE NAMES/SYNONYMS:
MTG MSDS 77; PROPENE; METHYLETHENE; METHYLETHYLENE; 1-PROPYLENE; 1-PROPENE; UN 1077; C3H6; MAT19830; RTECS UC6740000

CHEMICAL FAMILY: hydrocarbons, aliphatic

CREATION DATE: Jan 24 1989
REVISION DATE: Dec 11 2008

2. COMPOSITION, INFORMATION ON INGREDIENTS

COMPONENT: PROPYLENE
CAS NUMBER: 115-07-1
PERCENTAGE: 100.0

3. HAZARDS IDENTIFICATION

NFPA RATINGS (SCALE 0-4): HEALTH=1 FIRE=4 REACTIVITY=1

EMERGENCY OVERVIEW:
COLOR: colorless
PHYSICAL FORM: gas
MAJOR HEALTH HAZARDS: central nervous system depression, difficulty breathing
PHYSICAL HAZARDS: Flammable gas. May cause flash fire.

POTENTIAL HEALTH EFFECTS:
INHALATION:
SHORT TERM EXPOSURE: tearing, nausea, vomiting, symptoms of drunkenness, suffocation, convulsions, coma
LONG TERM EXPOSURE: no information on significant adverse effects

Section 11: Other Regulatory Controls

EPA/TSCA
The components of this product are listed on the EPA/TSCA inventory of chemical substances.

EPA Hazard Classification
This product is classified by 40 CFR 372 (SARA Section 313) as:

Acute Hazard	Chronic Hazard	Fire Hazard	Pressure Hazard	Reactive Hazard
XXX		XXX	XXX	

Ozone depleting substances
This product does not contain, nor was it directly manufactured with, any class I or class II ozone depleting substances.

RCRA Information
This product is not subject to 40CFR 268.30 ban on the disposal of hazardous wastes.
If this product becomes a waste material, it would be an ignitable hazardous waste, having a waste code number D0001. Refer to latest EPA or state regulations regarding proper disposal. Under EPA-RCRA, containers are considered hazardous unless depressurized to a pressure approaching atmospheric. Depressurize containers at a controlled rate to a flare.

State regulatory information
The ingredients in this product are specifically listed by individual states; other product specific health and safety data in other sections of the MSDS may also be applicable for state requirements.
- Contact the appropriate agency in your state for details on your regulatory requirements.

California Proposition 65 warning
Chemicals known to the State of California to cause cancer, birth defects, or other reproductive harm are created by the combustion of propane.

Section 12: Supplemental Information

Disclaimer of liability
The information in this MSDS was obtained from sources which we believe are reliable. **However, the information is provided without any warranty, express or implied, regarding its correctness.**

The conditions or methods of handling, storage, use and disposal of this product are beyond our control and may be beyond our knowledge. **For this and other reasons, we do not assume responsibility and expressly disclaim liability for loss, damage, or expense arising out of or in any way connected with the handling, storage, use, or disposal of this product.**

Issue information
This MSDS supersedes all previous editions.
- Issued July, 2008
- Issued by: Scott Fenimore, Manager of Safety
  Ferrellgas
  One Liberty Plaza
  Liberty, MO 64068

SKIN CONTACT:
SHORT TERM EXPOSURE: blisters, frostbite
LONG TERM EXPOSURE: no information is available
EYE CONTACT:
SHORT TERM EXPOSURE: frostbite, blurred vision
LONG TERM EXPOSURE: no information is available
INGESTION:
SHORT TERM EXPOSURE: frostbite
LONG TERM EXPOSURE: no information is available

4. FIRST AID MEASURES

INHALATION: If adverse effects occur, remove to uncontaminated area. Give artificial respiration if not breathing. If breathing is difficult, oxygen should be administered by qualified personnel. Get immediate medical attention.

SKIN CONTACT: If frostbite or freezing occur, immediately flush with plenty of lukewarm water (105-115 F; 41-46 C). DO NOT USE HOT WATER. If warm water is not available, gently wrap affected parts in blankets. Get immediate medical attention.

EYE CONTACT: Contact with liquid: Immediately flush eyes with plenty of water for at least 15 minutes. Then get immediate medical attention.

INGESTION: If a large amount is swallowed, get medical attention.

NOTE TO PHYSICIAN: For inhalation, consider oxygen.

5. FIRE FIGHTING MEASURES

FIRE AND EXPLOSION HAZARDS: Severe fire hazard. Vapor/air mixtures are explosive above flash point. The vapor is heavier than air. Vapors or gases may ignite at distant ignition sources and flash back. Electrostatic discharges may be generated by flow or agitation resulting in ignition or explosion.

EXTINGUISHING MEDIA: carbon dioxide, regular dry chemical

Large fires: Flood with fine water spray.

FIRE FIGHTING: Move container from fire area if it can be done without risk. Cool containers with water spray until well after the fire is out. Stay away from the ends of tanks. For fires in cargo or storage area: Cool containers with water from unmanned hose holder or monitor nozzles until well after fire is out. If this is impossible then take the following precautions: Keep unnecessary people away, isolate hazard area and deny entry. Let the fire burn. Withdraw immediately in case of rising sound from venting safety device or any discoloration of tanks due to fire. For tank, rail car or tank truck: Stop leak if possible without personal risk. Let burn unless leak can be stopped immediately. For smaller tanks or cylinders, extinguish and isolate from

other flammables. Evacuation radius: 800 meters (1/2 mile). Stop flow of gas.

FLASH POINT: -162 F (-108 C)
LOWER FLAMMABLE LIMIT: 2.0%
UPPER FLAMMABLE LIMIT: 11.1%
AUTOIGNITION: 851 F (455 C)

6. ACCIDENTAL RELEASE MEASURES

OCCUPATIONAL RELEASE:
Avoid heat, flames, sparks and other sources of ignition. Do not touch spilled material. Stop leak if possible without personal risk. Reduce vapors with water spray. Keep unnecessary people away, isolate hazard area and deny entry. Remove sources of ignition. Ventilate closed spaces before entering.

7. HANDLING AND STORAGE

STORAGE: Store and handle in accordance with all current regulations and standards. Subject to storage regulations: U.S. OSHA 29 CFR 1910.110. Protect from physical damage. Store in a cool, dry place. Store in a well-ventilated area. Avoid heat, flames, sparks and other sources of ignition. Store outside or in a detached building. Grounding and bonding required. Subject to storage regulations: U.S. OSHA 29 CFR 1910.101. Keep separated from incompatible substances.

8. EXPOSURE CONTROLS, PERSONAL PROTECTION

EXPOSURE LIMITS:
PROPYLENE:
500 ppm ACGIH TWA

VENTILATION: Ventilation equipment should be explosion-resistant if explosive concentrations of material are present. Provide local exhaust ventilation system. Ensure compliance with applicable exposure limits.

EYE PROTECTION: For the gas: Eye protection not required, but recommended. For the liquid: Wear splash resistant safety goggles. Contact lenses should not be worn. Provide an emergency eye wash fountain and quick drench shower in the immediate work area.

CLOTHING: For the gas: Protective clothing is not required. For the liquid: Wear appropriate protective, cold insulating clothing.

GLOVES: Wear insulated gloves.

RESPIRATOR: Under conditions of frequent use or heavy exposure, respiratory protection may be needed. Respiratory protection is ranked in order from minimum to maximum. Consider warning properties before

use.

For Unknown Concentrations or Immediately Dangerous to Life or Health -
Any supplied-air respirator with a full facepiece that is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive-pressure mode.
Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode.

9. PHYSICAL AND CHEMICAL PROPERTIES

PHYSICAL STATE: gas
COLOR: colorless
ODOR: Not available
MOLECULAR WEIGHT: 42.08
MOLECULAR FORMULA: C-H3-C-H-C-H2
BOILING POINT: -53 F (-47 C)
FREEZING POINT: -301 F (-185 C)
VAPOR PRESSURE: 7828 mmHg @ 21.1 C
VAPOR DENSITY (air=1): 1.5
SPECIFIC GRAVITY: Not applicable
DENSITY: 1.7855 g/L
WATER SOLUBILITY: 45%
PH: Not applicable
VOLATILITY: Not applicable
ODOR THRESHOLD: Not available
EVAPORATION RATE: Not applicable
VISCOSITY: 0.140 cP @ -40 C
COEFFICIENT OF WATER/OIL DISTRIBUTION: Not applicable
SOLVENT SOLUBILITY:
Soluble: alcohol, ether, acetic acid

10. STABILITY AND REACTIVITY

REACTIVITY: May polymerize. May react on contact with air, heat, light or water.

CONDITIONS TO AVOID: Avoid heat, flames, sparks and other sources of ignition. Minimize contact with material. Containers may rupture or explode if exposed to heat.

INCOMPATIBILITIES: oxidizing materials, halo carbons, halogens, acids

HAZARDOUS DECOMPOSITION:
Thermal decomposition products: miscellaneous decomposition products

POLYMERIZATION: May polymerize. Avoid contact with heat, light, air, water or incompatible materials. Polymerizes with evolution of heat.

11. TOXICOLOGICAL INFORMATION

PROPYLENE:
CARCINOGEN STATUS: IARC: Human Inadequate Evidence, Animal Inadequate Evidence, Group 3; ACGIH: A4 -Not Classifiable as a Human Carcinogen
TARGET ORGANS: central nervous system
TUMORIGENIC DATA: Available.
MUTAGENIC DATA: Available.
ADDITIONAL DATA: Stimulants such as epinephrine may induce ventricular fibrillation.

12. ECOLOGICAL INFORMATION

FATE AND TRANSPORT:
KOW: 223.87 (log = 2.35) (estimated from water solubility)

KOC: 533.33 (log = 2.73) (estimated from water solubility)

HENRY'S LAW CONSTANT: 9.6 E -4 atm-m3/mol

BIOCONCENTRATION: 0.40 (estimated from water solubility)

AQUATIC PROCESSES: 1.6862069 hours (River Model: 1 m deep, 1 m/s flow, 3 m/s wind)

ENVIRONMENTAL SUMMARY: Relatively non-persistent in the environment. Leaches through the soil or the sediment at a slow rate. Accumulates very little in the bodies of living organisms. Moderately volatile from water.

13. DISPOSAL CONSIDERATIONS

Dispose in accordance with all applicable regulations. Subject to disposal regulations: U.S. EPA 40 CFR 262. Hazardous Waste Number(s): D001.

14. TRANSPORT INFORMATION

U.S. DOT 49 CFR 172.101:
PROPER SHIPPING NAME: Propylene
ID NUMBER: UN1077
HAZARD CLASS OR DIVISION: 2.1
LABELING REQUIREMENTS: 2.1

SAFETY DATA SHEET

Version 4.12
Revision Date 04/30/2015
Print Date 04/01/2016

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product identifiers

Product name : Zirconium(IV) oxide-yttria stabilized

Product Number : 572349
Brand : Aldrich

CAS-No. : 114168-16-0

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Manufacture of substances

1.3 Details of the supplier of the safety data sheet

Company : Sigma-Aldrich
3050 Spruce Street
SAINT LOUIS MO 63103
USA

Telephone : +1 800-325-5832
Fax : +1 800-325-5052

1.4 Emergency telephone number

Emergency Phone # : (314) 776-6555

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)
Skin irritation (Category 2), H315
Eye irritation (Category 2A), H319
Specific target organ toxicity - single exposure (Category 3), Respiratory system, H335

For the full text of the H-Statements mentioned in this Section, see Section 16.

2.2 GHS Label elements, including precautionary statements

Pictogram

Signal word Warning

Hazard statement(s)
H315 Causes skin irritation.
H319 Causes serious eye irritation.
H335 May cause respiratory irritation.

Precautionary statement(s)
P261 Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P264 Wash skin thoroughly after handling.
P271 Use only outdoors or in a well-ventilated area.
P280 Wear protective gloves/ eye protection/ face protection.
P302 + P352 IF ON SKIN: Wash with plenty of soap and water.
P304 + P340 IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.
P305 + P351 + P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove

QUANTITY LIMITATIONS:
PASSENGER AIRCRAFT OR RAILCAR: Forbidden
CARGO AIRCRAFT ONLY: 150 kg

CANADIAN TRANSPORTATION OF DANGEROUS GOODS:
SHIPPING NAME: Propylene
UN NUMBER: UN1077
CLASS: 2.1

15. REGULATORY INFORMATION

U.S. REGULATIONS:
CERCLA SECTIONS 102a/103 HAZARDOUS SUBSTANCES (40 CFR 302.4): Not regulated.

SARA TITLE III SECTION 302 EXTREMELY HAZARDOUS SUBSTANCES (40 CFR 355 Subpart B): Not regulated.

SARA TITLE III SECTION 304 EXTREMELY HAZARDOUS SUBSTANCES (40 CFR 355 Subpart C): Not regulated.

SARA TITLE III SARA SECTIONS 311/312 HAZARDOUS CATEGORIES (40 CFR 370 Subparts B and C):
ACUTE: Yes
CHRONIC: No
FIRE: Yes
REACTIVE: No
SUDDEN RELEASE: Yes

SARA TITLE III SECTION 313 (40 CFR 372.65):
PROPYLENE

OSHA PROCESS SAFETY (29 CFR 1910.119): Not regulated.

STATE REGULATIONS:
California Proposition 65: Not regulated.

CANADIAN REGULATIONS:
WHMIS CLASSIFICATION: A, B1.

NATIONAL INVENTORY STATUS:
U.S. INVENTORY (TSCA): Listed on inventory.

TSCA 12(b) EXPORT NOTIFICATION: Not listed.

CANADA INVENTORY (DSL/NDSL): Listed on inventory.

5.2 Special hazards arising from the substance or mixture
Zirconium oxides, Yttrium oxides

5.3 Advice for firefighters
Wear self-contained breathing apparatus for firefighting if necessary.

5.4 Further information
No data available

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures
Use personal protective equipment. Avoid dust formation. Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Evacuate personnel to safe areas. Avoid breathing dust.
For personal protection see section 8.

6.2 Environmental precautions
Do not let product enter drains.

6.3 Methods and materials for containment and cleaning up
Pick up and arrange disposal without creating dust. Sweep up and shovel. Keep in suitable, closed containers for disposal.

6.4 Reference to other sections
For disposal see section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling
Avoid contact with skin and eyes. Avoid formation of dust and aerosols.
Provide appropriate exhaust ventilation at places where dust is formed.
For precautions see section 2.2.

7.2 Conditions for safe storage, including any incompatibilities
Keep container tightly closed in a dry and well-ventilated place.

Keep in a dry place.

7.3 Specific end use(s)
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters

Component	CAS-No.	Value	Control parameters	Basis
Yttrium oxide	1314-36-9	TWA	1.000000 mg/m3	USA. ACGIH Threshold Limit Values (TLV)
	Remarks	Pulmonary fibrosis		
		TWA	1 mg/m3	USA. ACGIH Threshold Limit Values (TLV)
		Pulmonary fibrosis		
		TWA	1.000000 mg/m3	USA. NIOSH Recommended Exposure Limits

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166 Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

contact lenses, if present and easy to do. Continue rinsing.

P312	Call a POISON CENTER or doctor/ physician if you feel unwell.
P321	Specific treatment (see supplemental first aid instructions on this label).
P332 + P313	If skin irritation occurs: Get medical advice/ attention.
P337 + P313	If eye irritation persists: Get medical advice/ attention.
P362	Take off contaminated clothing and wash before reuse.
P403 + P233	Store in a well-ventilated place. Keep container tightly closed.
P405	Store locked up.
P501	Dispose of contents/ container to an approved waste disposal plant.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

3. COMPOSITION/INFORMATION ON INGREDIENTS

3.1 Substances

Synonyms	:	YSZ
Formula	:	O_5Y_2Zr
Molecular weight	:	349.03 g/mol
CAS-No.	:	114168-16-0

Hazardous components

Component	Classification	Concentration
Zirconium (IV) oxide, yttria stabilized		
	Skin Irrit. 2; Eye Irrit. 2A; STOT SE 3; H315, H319, H335	<= 100 %
Yttrium oxide		
	Skin Irrit. 2; STOT SE 3; H315, H335	>= 5 - < 10 %

No components need to be disclosed according to the applicable regulations.
For the full text of the H-Statements mentioned in this Section, see Section 16.

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance.Move out of dangerous area.

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact
Wash off with soap and plenty of water. Consult a physician.

In case of eye contact
Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.

If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

4.3 Indication of any immediate medical attention and special treatment needed
No data available

5. FIREFIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

Skin protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body Protection
impervious clothing, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Respiratory protection
For nuisance exposures use type P95 (US) or type P1 (EU EN 143) particle respirator.For higher level protection use type OV/AG/P99 (US) or type ABEK-P2 (EU EN 143) respirator cartridges. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Control of environmental exposure
Do not let product enter drains.

9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: powder
b)	Odour	No data available
c)	Odour Threshold	No data available
d)	pH	No data available
e)	Melting point/freezing point	Melting point/range: > 2.6 °C (> 36.7 °F) - lit.
f)	Initial boiling point and boiling range	No data available
g)	Flash point	Not applicable
h)	Evaporation rate	No data available
i)	Flammability (solid, gas)	No data available
j)	Upper/lower flammability or explosive limits	No data available
k)	Vapour pressure	No data available
l)	Vapour density	No data available
m)	Relative density	No data available
n)	Water solubility	No data available
o)	Partition coefficient: n-octanol/water	No data available
p)	Auto-ignition temperature	No data available
q)	Decomposition temperature	No data available
r)	Viscosity	No data available
s)	Explosive properties	No data available
t)	Oxidizing properties	No data available

9.2 Other safety information
No data available

10. STABILITY AND REACTIVITY

10.1 Reactivity
No data available

10.2 Chemical stability
Stable under recommended storage conditions.
Contains the following stabiliser(s):
Yttrium oxide (8 %)

10.3 Possibility of hazardous reactions
No data available

10.4 Conditions to avoid
No data available

10.5 Incompatible materials
Strong oxidizing agentsStrong oxidizing agentsStrong oxidizing agents

10.6 Hazardous decomposition products
Other decomposition products - No data available
In the event of fire: see section 5

11. TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity
No data available

Inhalation: No data available

Dermal: No data available

No data available

Skin corrosion/irritation
No data available

Serious eye damage/eye irritation
No data available

Respiratory or skin sensitisation
No data available

Germ cell mutagenicity
No data available

Carcinogenicity

IARC:	No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.
ACGIH:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.
NTP:	No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.
OSHA:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity
No data available

No data available

Specific target organ toxicity - single exposure
No data available

SARA 311/312 Hazards
Acute Health Hazard

Massachusetts Right To Know Components
No components are subject to the Massachusetts Right to Know Act.

Pennsylvania Right To Know Components

	CAS-No.	Revision Date
Zirconium (IV) oxide, yttria stabilized	114168-16-0	
Yttrium oxide	1314-36-9	

New Jersey Right To Know Components

	CAS-No.	Revision Date
Zirconium (IV) oxide, yttria stabilized	114168-16-0	
Yttrium oxide	1314-36-9	

California Prop. 65 Components
This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

16. OTHER INFORMATION

Full text of H-Statements referred to under sections 2 and 3.

Eye Irrit.	Eye irritation
H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.
Skin Irrit.	Skin irritation
STOT SE	Specific target organ toxicity - single exposure

HMIS Rating

Health hazard:	2
Chronic Health Hazard:	
Flammability:	0
Physical Hazard	0

NFPA Rating

Health hazard:	2
Fire Hazard:	0
Reactivity Hazard:	0

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

Preparation Information
Sigma-Aldrich Corporation
Product Safety – Americas Region
1-800-521-8956

Version: 4.12 Revision Date: 04/30/2015 Print Date: 04/01/2016

Specific target organ toxicity - repeated exposure
No data available

Aspiration hazard
No data available

Additional Information
RTECS: Not available

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.
To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.
To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity
No data available

12.2 Persistence and degradability
No data available

12.3 Bioaccumulative potential
No data available

12.4 Mobility in soil
No data available

12.5 Results of PBT and vPvB assessment
PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

12.6 Other adverse effects

No data available

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Offer surplus and non-recyclable solutions to a licensed disposal company. Contact a licensed professional waste disposal service to dispose of this material.

Contaminated packaging
Dispose of as unused product.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods

IMDG
Not dangerous goods

IATA
Not dangerous goods

15. REGULATORY INFORMATION

SARA 302 Components
No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

P264	Wash skin thoroughly after handling.
P270	Do not eat, drink or smoke when using this product.
P271	Use only outdoors or in a well-ventilated area.
P280	Wear protective gloves/ eye protection/ face protection.
P301 + P312 + P330	IF SWALLOWED: Call a POISON CENTER or doctor/ physician if you feel unwell. Rinse mouth.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P304 + P340 + P312	IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing. Call a POISON CENTER or doctor/ physician if you feel unwell.
P305 + P351 + P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P332 + P313	If skin irritation occurs: Get medical advice/ attention.
P337 + P313	If eye irritation persists: Get medical advice/ attention.
P362	Take off contaminated clothing and wash before reuse.
P370 + P378	In case of fire: Use dry sand, dry chemical or alcohol-resistant foam for extinction.
P403 + P233	Store in a well-ventilated place. Keep container tightly closed.
P405	Store locked up.
P501	Dispose of contents/ container to an approved waste disposal plant.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

3. COMPOSITION/INFORMATION ON INGREDIENTS

3.1 Substances

Formula	:	$N_2O_6Zn \cdot 6H_2O$
Molecular weight	:	297.49 g/mol
CAS-No.	:	10196-18-6
EC-No.	:	231-943-8

Hazardous components

Component	Classification	Concentration
Zinc nitrate hexahydrate		
	Ox. Sol. 2; Acute Tox. 4; Skin Irrit. 2; Eye Irrit. 2A; STOT SE 3; H272, H302, H315, H319, H335	<= 100 %

For the full text of the H-Statements mentioned in this Section, see Section 16.

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance.Move out of dangerous area.

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact
Wash off with soap and plenty of water. Consult a physician.

In case of eye contact
Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.Continue rinsing eyes during transport to hospital.

If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

SAFETY DATA SHEET

Version 3.5
Revision Date 11/19/2014
Print Date 04/01/2016

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product identifiers

Product name	:	Zinc nitrate hexahydrate
Product Number	:	96482
Brand	:	Sigma-Aldrich
CAS-No.	:	10196-18-6

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Manufacture of substances

1.3 Details of the supplier of the safety data sheet

Company : Sigma-Aldrich
3050 Spruce Street
SAINT LOUIS MO 63103
USA

Telephone : +1 800-325-5832
Fax : +1 800-325-5052

1.4 Emergency telephone number

Emergency Phone # : (314) 776-6555

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)
Oxidizing solids (Category 2), H272
Acute toxicity, Oral (Category 4), H302
Skin irritation (Category 2), H315
Eye irritation (Category 2A), H319
Specific target organ toxicity - single exposure (Category 3), Respiratory system, H335

For the full text of the H-Statements mentioned in this Section, see Section 16.

2.2 GHS Label elements, including precautionary statements

Pictogram

Signal word Danger

Hazard statement(s)	
H272	May intensify fire; oxidiser.
H302	Harmful if swallowed.
H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.

Precautionary statement(s)	
P210	Keep away from heat.
P220	Keep/Store away from clothing/ combustible materials.
P221	Take any precaution to avoid mixing with combustibles.
P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166 Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Full contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

Splash contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

Body Protection
Complete suit protecting against chemicals, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Respiratory protection
Where risk assessment shows air-purifying respirators are appropriate use a full-face particle respirator type N100 (US) or type P3 (EN 143) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Control of environmental exposure
Do not let product enter drains.

9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: crystalline Colour: colourless
b)	Odour	No data available
c)	Odour Threshold	No data available
d)	pH	No data available
e)	Melting point/freezing point	Melting point/range: 36 °C (97 °F)
f)	Initial boiling point and boiling range	No data available
g)	Flash point	Not applicable
h)	Evaporation rate	No data available
i)	Flammability (solid, gas)	No data available
j)	Upper/lower flammability or	No data available

4.3 Indication of any immediate medical attention and special treatment needed
No data available

5. FIREFIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

5.2 Special hazards arising from the substance or mixture
Zinc/zinc oxides

5.3 Advice for firefighters
Wear self-contained breathing apparatus for firefighting if necessary.

5.4 Further information
Use water spray to cool unopened containers.

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures
Use personal protective equipment. Avoid dust formation. Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Evacuate personnel to safe areas. Avoid breathing dust.
For personal protection see section 8.

6.2 Environmental precautions
Do not let product enter drains.

6.3 Methods and materials for containment and cleaning up
Sweep up and shovel. Contain spillage, and then collect with an electrically protected vacuum cleaner or by wet-brushing and place in container for disposal according to local regulations (see section 13). Keep in suitable, closed containers for disposal.

6.4 Reference to other sections
For disposal see section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling
Avoid contact with skin and eyes. Avoid formation of dust and aerosols.Further processing of solid materials may result in the formation of combustible dusts. The potential for combustible dust formation should be taken into consideration before additional processing occurs.
Provide appropriate exhaust ventilation at places where dust is formed.Keep away from sources of ignition - No smoking.Keep away from heat and sources of ignition.
For precautions see section 2.2.

7.2 Conditions for safe storage, including any incompatibilities
Keep container tightly closed in a dry and well-ventilated place.

Hygroscopic.
Storage class (TRGS 510): Oxidizing hazardous materials

7.3 Specific end use(s)
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
Contains no substances with occupational exposure limit values.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

explosive limits

k)	Vapour pressure	No data available
l)	Vapour density	No data available
m)	Relative density	2.065 g/cm3
n)	Water solubility	No data available
o)	Partition coefficient: n-octanol/water	No data available
p)	Auto-ignition temperature	No data available
q)	Decomposition temperature	No data available
r)	Viscosity	No data available
s)	Explosive properties	No data available
t)	Oxidizing properties	The substance or mixture is classified as oxidizing with the category 2.

9.2 Other safety information
No data available

10. STABILITY AND REACTIVITY

10.1 Reactivity
No data available

10.2 Chemical stability
Stable under recommended storage conditions.

10.3 Possibility of hazardous reactions
No data available

10.4 Conditions to avoid
hygroscopic

10.5 Incompatible materials
Powdered metals, Cyanides, Sodium hypophosphite, Stannous chloride, Thiocyanates, Strong reducing agents

10.6 Hazardous decomposition products
Other decomposition products - No data available
In the event of fire: see section 5

11. TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity
LD50 Oral - Rat - 1,190 mg/kg

Dermal: No data available

No data available

Skin corrosion/irritation
Skin - Rabbit
Result: Severe skin irritation - 24 h

Serious eye damage/eye irritation
Eyes - Rabbit
Result: Moderate eye irritation - 24 h

Respiratory or skin sensitisation
No data available

Germ cell mutagenicity
No data available

Carcinogenicity

IARC:	No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.
ACGIH:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.
NTP:	No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.
OSHA:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity
No data available

No data available

Specific target organ toxicity - single exposure
Inhalation - May cause respiratory irritation.

Specific target organ toxicity - repeated exposure
No data available

Aspiration hazard
No data available

Additional Information
RTECS: ZH4775000

Fever, Cough, Nausea, Vomiting, Weakness

Stomach - Irregularities - Based on Human Evidence
Stomach - Irregularities - Based on Human Evidence

12. ECOLOGICAL INFORMATION

12.1 Toxicity
No data available

12.2 Persistence and degradability
No data available

12.3 Bioaccumulative potential
No data available

12.4 Mobility in soil
No data available

12.5 Results of PBT and vPvB assessment
PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

12.6 Other adverse effects

No data available

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Burn in a chemical incinerator equipped with an afterburner and scrubber but exert extra care in igniting as this material is highly flammable. Offer surplus and non-recyclable solutions to a licensed disposal company. Contact a licensed professional waste disposal service to dispose of this material. Dissolve or mix the material with a combustible solvent and burn in a chemical incinerator equipped with an afterburner and scrubber.

Contaminated packaging
Dispose of as unused product.

Chronic Health Hazard:	*
Flammability:	0
Physical Hazard	2

NFPA Rating

Health hazard:	3
Fire Hazard:	0
Reactivity Hazard:	2
Special hazard.l:	OX

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

Preparation Information

Sigma-Aldrich Corporation
Product Safety – Americas Region
1-800-521-8956

Version: 3.5 Revision Date: 11/19/2014 Print Date: 04/01/2016

14. TRANSPORT INFORMATION

DOT (US)
UN number: 1514 Class: 5.1 Packing group: II
Proper shipping name: Zinc nitrate
Reportable Quantity (RQ): 1000 lbs

Poison Inhalation Hazard: No

IMDG
UN number: 1514 Class: 5.1 Packing group: II EMS-No: F-H, S-Q
Proper shipping name: ZINC NITRATE

IATA
UN number: 1514 Class: 5.1 Packing group: II
Proper shipping name: Zinc nitrate

15. REGULATORY INFORMATION

SARA 302 Components
No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
The following components are subject to reporting levels established by SARA Title III, Section 313:

	CAS-No.	Revision Date
Zinc nitrate hexahydrate	10196-18-6	1993-04-24

SARA 311/312 Hazards
Reactivity Hazard, Acute Health Hazard, Chronic Health Hazard

Massachusetts Right To Know Components

	CAS-No.	Revision Date
Zinc nitrate hexahydrate	10196-18-6	1993-04-24

Pennsylvania Right To Know Components

	CAS-No.	Revision Date
Zinc nitrate hexahydrate	10196-18-6	1993-04-24

New Jersey Right To Know Components

	CAS-No.	Revision Date
Zinc nitrate hexahydrate	10196-18-6	1993-04-24

California Prop. 65 Components
This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

16. OTHER INFORMATION

Full text of H-Statements referred to under sections 2 and 3.

Acute Tox.	Acute toxicity
Eye Irrit.	Eye irritation
H272	May intensify fire; oxidiser.
H302	Harmful if swallowed.
H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.
Ox. Sol.	Oxidizing solids
Skin Irrit.	Skin irritation

HMIS Rating

Health hazard:	3